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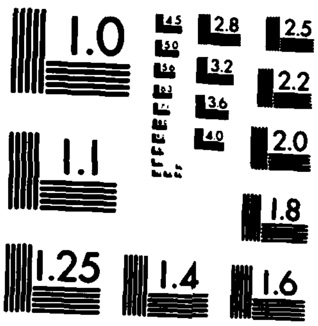
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DTNSRDC/SPD-0957-03

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

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ANALYSIS OF WAKE SURVEY DATA FOR A SALVAGE SHIP (ARS-50) DESIGN REPRESENTED BY MODEL 5391 WITH KORT NOZZLE

By

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and

E. E. West

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SHIP PERFORMANCE DEPARTMENT

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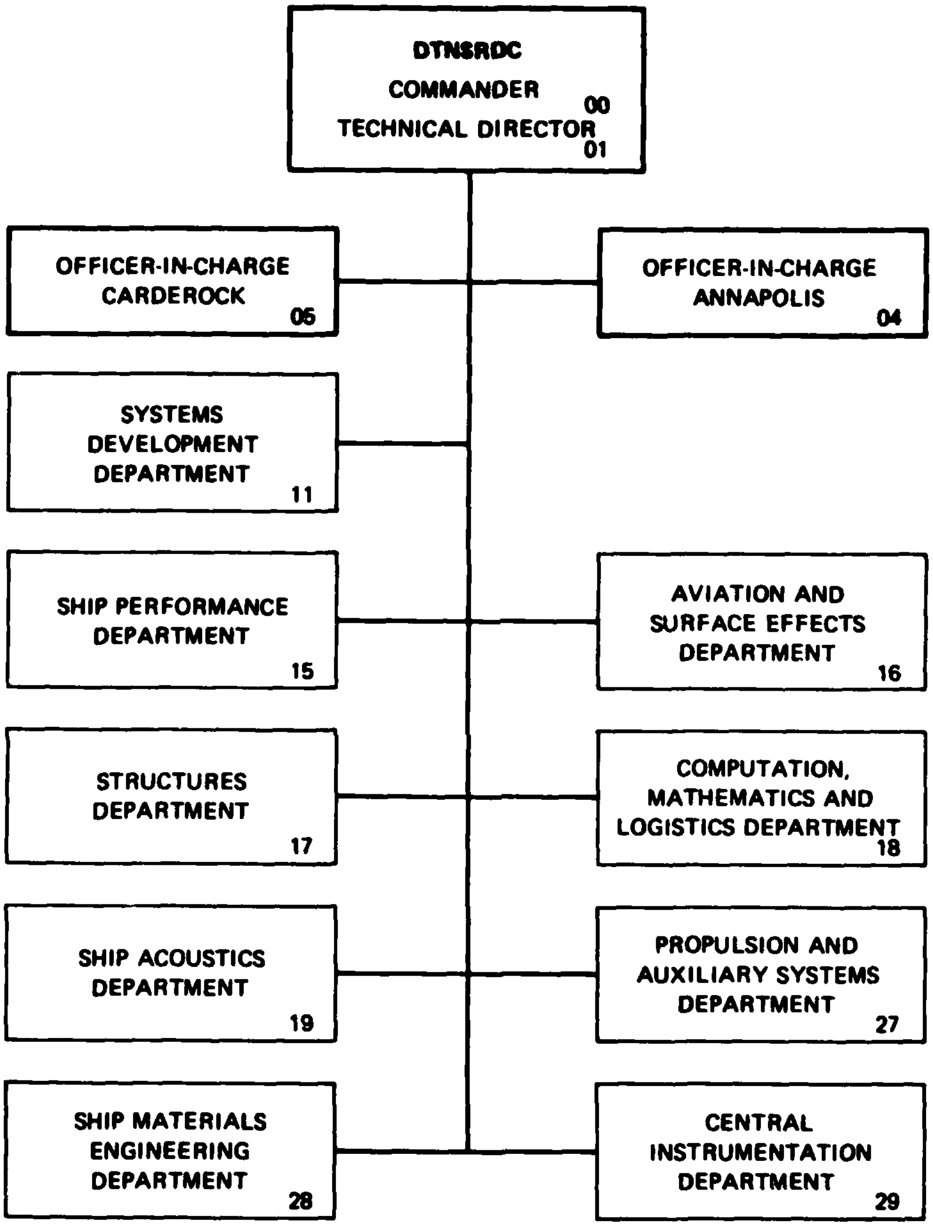

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A wake survey was conducted to aid in the design of a kort nozzle propeller for a salvage ship (ARS-50) represented by DTNSRDC Model 5391-1 (Hydronautics Model 7925-4). Pressure measurements were made with a rake of five-hole pitot tubes in order to obtain the flow velocity in the plane of the propeller. Several model configurations were tested in order to identify the effect of the nozzle on the flow and also the effect of a propeller installed just aft of the rake for the purpose of simulating a realistic flow

20. Abstract (continued)

through the nozzle. Harmonic analyses of the circumferential distribution of the velocity component ratios were performed on the model experimental data and the results are reported herein.

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NOTATION

CONVENTIONAL SYMBOL	SYMBOL APPEARING ON PLOTS	DEFINITION
A_N	COS COEF	The cosine coefficient of the N^{th} harmonic*
B_N	SIN COEF	The sine coefficient of the N^{th} harmonic*
D	---	Propeller diameter
J_V	---	Apparent advance coefficient $J_V = \frac{V}{nD}$ (dimensionless)
L	---	Length of ship (LBP)
N	N	Harmonic number
n	---	Propeller revolutions
r/R or x	Radius or RAD.	Distance (r) from the propeller axis expressed as a ratio of the propeller radius (R)
V	V	Actual model or ship velocity
$V_b(x,\theta)$	---	Resultant inflow velocity to blade for a given point
$\bar{V}_b(x)$	---	Mean resultant inflow velocity to blade for a given radius
$V_r(x,\theta)$	VR	Radial component of the fluid velocity for a given point (positive toward the shaft centerline)
$\bar{V}_r(x)$	---	Mean radial velocity component for a given radius
$V_r(x,\theta)/V$	VR/V	Radial velocity component ratio for a given point
$\bar{V}_r(x)/V$	VRBAR	Mean radial velocity component ratio for a given radius
$V_t(x,\theta)$	VT	Tangential component of the fluid velocity for a given point (positive in a counterclockwise direction looking forward)

*See footnote on the following page

NOTATION (Continued)

$\bar{V}_t(x)$	---	Mean tangential velocity component for a given radius
$V_t(x,\theta)/V$	VT/V	Tangential velocity component ratio for a given point
$\bar{V}_t(x)/V$	VTBAR	Mean tangential velocity component ratio for a given radius
$(\tilde{V}_t(x)/V)_N$	AMPLITUDE	Amplitude (B_N for single screw symmetric; C_N otherwise) of Nth harmonic of the tangential velocity component ratio for a given radius*
$V_x(x,\theta)$	VX	Longitudinal (normal to the plane of survey) component of the fluid velocity for a given point (positive in the astern direction)
$\bar{V}_x(x)$	---	Mean longitudinal velocity component for a given radius
$V_x(x,\theta)/V$	VX/V	Longitudinal velocity component ratio for a given point
$\bar{V}_x(x)/V$	VXBAR	Mean longitudinal velocity component ratio for a given radius
$(\tilde{V}_x(x)/V)_N$	AMPLITUDE	Amplitude (A_N for single screw symmetric; C_N otherwise) of Nth harmonic of the longitudinal velocity component ratio for a given radius*
ϕ_N	PHASE ANGLE	Phase Angle of Nth harmonic*

*The harmonic amplitudes of any circumferential velocity distribution $f(\theta)$ are the coefficients of the Fourier Series:

$$f(\theta) = A_o + \sum_{N=1}^{N} A_N \cos(N\theta) + \sum_{N=1}^{N} B_N \sin(N\theta)$$

$$= A_o + \sum_{N=1}^{N} C_N \sin(N\theta + \phi_N)$$

NOTATION (Continued)

$1-w(x)$ 1-WX   Volumetric mean velocity ratio from the hub to a given radius

$$1-w(r/R) = \left[\frac{2 \cdot \int_{r_{hub}/R}^{r/R} (\bar{V}_{x_c}(x)/V) \cdot x \cdot dx}{(r/R)^2 - (r_{hub}/R)^2} \right]$$

where $\bar{V}_{x_c}(x)/V = \int_0^{2\pi} \left[\frac{V_{x_c}(x,\theta)}{2\pi V} \right] d\theta$

and $V_{x_c}(x,\theta)/V) = (V_x(x,\theta)/V)$
$-(V_t(x,\theta)/V) \tan(\beta(x,\theta))$

$1-w_v(x)$ 1-WVX   Volumetric mean velocity ratio from the hub to a given radius (without the tangential velocity correction)

$$1-w(r/R) = \left[\frac{2 \cdot \int_{r_{hub}/R}^{r/R} (\bar{V}_x(x)/V) \cdot x \cdot dx}{(r/R)^2 - (r_{hub}/R)^2} \right]$$

x/L Distance from forward perpendicular expressed as a ratio of the overall length (L)

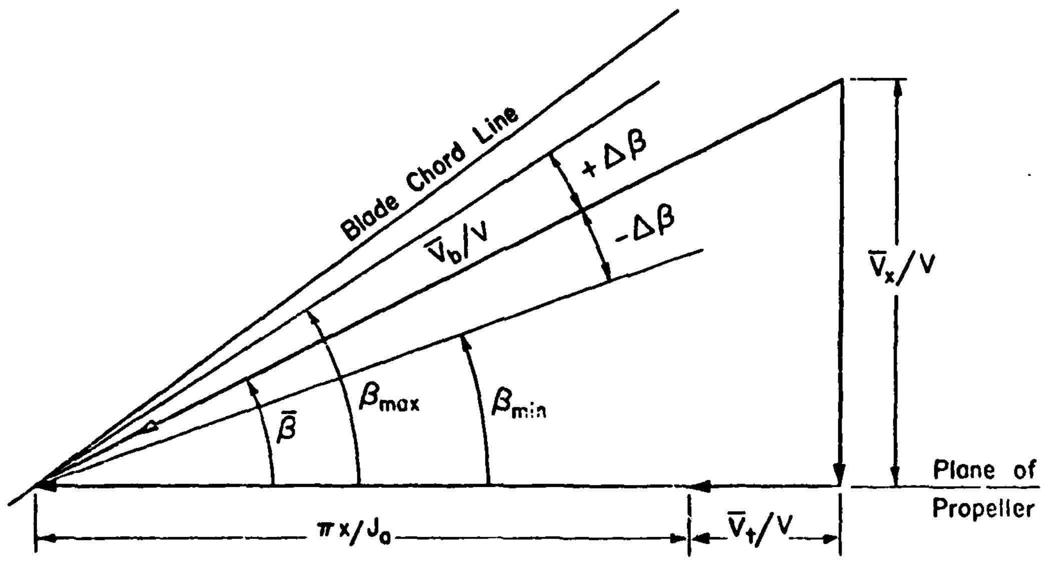
$\beta(x,\theta)$ ---   Advance angle in degrees for a given point

$\bar{\beta}(x)$ BBAR   Mean advance angle in degrees for a given radius

$+\Delta\beta$ BPOS   Variation of the maximum advance angle from the mean for a given radius

NOTATION (Continued)

$-\Delta\beta$	BNEG	Variation of the minimum advance angle from the mean for a given radius
θ	Angle in Degrees	Position angle (angular coordinate) in degrees



VELOCITY DIAGRAM OF BETA ANGLES

AMERICAN STANDARD AND METRIC EQUIVALENTS (U)

AMERICAN STANDARD	METRIC
1 inch	25.400 millimeter [0.0254 m (meter)]
1 foot	0.3048 m (meter)
1 foot per second	0.3048 m/s (meter per second)
1 knot	0.5144 m/s (meter per second)
1 pound (force)	4.4480 N (newtons)
1 degree (angle)	0.01745 rad (radians)
1 horsepower	0.7457 kW (kilowatts)
1 long ton	1.016 tonnes, 1.016 metric tons, or 1016.0 kilograms
1 inch water (60 deg F)	248.8 pa (pascals)

The notations used in this document are consistent with the International Towing Tank Conference (ITTC) Standard Symbols.*

*International Towing Tank Conference Standard Symbols 1976, The British Ship Research Association, BSRA Technical Memorandum No. 500 (May 1976)

ABSTRACT

A wake survey was conducted to aid in the design of a kort nozzle propeller for a salvage ship (ARS-50) represented by DTNSRDC Model 5391-1 (Hydronautics Model 7925-4). Pressure measurements were made with a rake of five-hole pitot tubes in order to obtain the flow velocity in the plane of the propeller. Several model configurations were tested in order to identify the effect of the nozzle on the flow and also the effect of a propeller installed just aft of the rake for the purpose of simulating a realistic flow through the nozzle. Harmonic analyses of the circumferential distribution of the velocity component ratios were performed on the model experimental data and the results are reported herein.

ADMINISTRATIVE INFORMATION

The work was authorized by the Naval Sea Systems Command (NAVSEA) in accordance with Work Request Number N00024-82. The DTNSRDC Work Unit Number was 1521-730.

INTRODUCTION

The Naval Sea Systems Command (NAVSEA) initiated a model experimental program at the David W. Taylor Naval Ship R&D Center (DTNSRDC) to aid in the calculation of alternating forces and moments of the ARS-50 salvage ship propeller. In this program, the Center was requested to perform wake surveys in the propeller plane of the ARS-50 Model with the kort nozzles. One survey was to be conducted while a propeller was operating to induce flow through the nozzle. A second survey was to be performed with the propeller removed. An additional wake survey was performed without the nozzle or propeller.

A powering investigation as well as a wake survey had been carried out by Anderson and Day[1] with the model of the ARS 50 fitted with an unshrouded propeller instead of the present kort nozzle propulsion system. The results of

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[1] References are listed on page 7.

the wake survey with and without the kort nozzle and the harmonic analyses of the velocity components of the survey are presented herein.

DESCRIPTION OF MODEL

Model 5391, representing the 240 ft (73.1 m) ARS-50 salvage ship, was constructed of fiberglass by Hydronautics Inc. for experiments requested of them by NAVSEA. The linear ratio used was 15.357.

The appendages installed for the wake survey in addition to the kort nozzles included the shafts, struts, and bilge keels. A right angle drive was also installed to power the propeller (Hydronautics propeller 7925-2CD set at pitch-diameter ratio of 1.21) behind the kort nozzle. Photographs of the arrangement are shown in Figure 1. The appendage arrangement with the propeller removed for the wake survey without the induced flow through the kort nozzle is shown in Figure 2.

The wake surveys were conducted with the model ballasted to a draft representing 15.5 ft (4.7 m) even keel in the static condition. The model was then towed at a velocity representing a ship speed of 14.5 knots (7.5 m/s). Propeller revolutions representing 150 revolutions per minute (rpm) full-scale were set when the propeller was used.

A special wake survey rake was built with short pitot tubes so that the rake would be suitable for operation within the nozzle and have as small a clearance as possible from the operating propeller mounted just behind the rake. A drawing of the pitot tube rake arrangement is presented in Figure 3. The tubes were positioned radially at fractions of the propeller radius equalling 0.451, 0.591, 0.735, and 0.868, based on a 5.25 ft (1.6 m) propeller radius.

PRESENTATION AND DISCUSSION OF RESULTS

This presentation is divided into three sections, the wake survey in the nozzle with the propeller induced flow, the survey in the nozzle without the propeller, and the survey without the nozzle or propeller. The advance angles were calculated using an advance coefficient, J_V, of 0.910.

WITH PROPELLER

The circumferential distributions of the longitudinal, tangential, and radial velocity component ratios of the propeller induced flow are presented in graphical form in Figures 4 through 7. Tabulated values of the experimental velocity component ratios at the experimental radii are presented in Table 1. The radial distributions of the circumferential mean velocities and advance angles are plotted in Figures 8 and 9, respectively.

Harmonic analyses have been performed on the longitudinal and tangential velocity component ratios. The mean longitudinal (VXBAR), tangential (VTBAR), and radial (VRBAR) component ratios of the velocity vectors, and the volumetric mean wake velocity ratio (1-WX) are presented in Table 2 along with the calculated mean values of the advance angle (BBAR), and the maximum variations thereof, (BPOS) and (BNEG). The amplitudes and phase angles for the four experimental and nine interpolated radii are tabulated for eight harmonics in Tables 3 and 4 for the longitudinal and tangential velocity components, respectively.

WITHOUT PROPELLER

The circumferential distributions of the longitudinal, tangential, and radial velocity component ratios for the survey without the propeller are presented in graphical form in Figures 10 and 13. Tabulated values of the

experimental velocity component ratios at the experimental radii are presented in Table 5. The radial distributions of the circumferential mean velocities and advance angles are plotted in Figures 14 and 15, respectively and tabulated in Table 6. The amplitudes and phase angles from the harmonic analysis of the wake survey without the propeller are presented in Tables 7 and 8.

WITHOUT NOZZLE

The circumferential distributions of velocity component ratios for the survey without the nozzle or propeller are presented in graphical form in Figures 16 through 19. Tabulated values of the experimental velocity component ratios at the experimental radii are presented in Table 9. The radial distribution of the mean velocity component ratios and advance angles are plotted in Figures 20 and 21 respectively and tabulated in Table 10. This data was collected for comparison with reference 1. The amplitudes and phase angles from the harmonic analysis of the wake survey without the nozzle are presented in Tables 11 and 12.

In Figures 8, 9, 13, 14, 20, and 21, points marked by geometric symbols (triangle, square, etc.) represent actual measured data. The points marked by an "x" represent interpolations calculated by the computer.

The measurement system used in this velocity survey has been described by Grant and Lin[2]. The accuracy of the pressure transducer system is approximately plus or minus three hundredths of an inch of water pressure (7.5 pascal). The accuracy of the entire velocity survey apparatus is estimated to be $\pm$ one percentage point on the longitudinal velocity component ratio, except in areas where steep velocity gradients occur. In these areas, such as behind a strut, the accuracy is significantly less.

Figure 22 presents a composite plot of the radial distribution of the mean longitudinal velocity component to illustrate the increase in flow velocity caused by the nozzle and propeller. The nozzle caused an increase in the axial flow through the propeller plane of approximately 6.5 percent while the propeller increased the flow through the nozzle by approximately 18.8 percent.

The tangential velocity component ratios were not affected appreciably by the flow velocity increase due to the nozzle or propeller.

The tangential velocity component ratios measured with the second and fourth pitot tubes (r/R values of 0.591 and 0.868) were considered to be too high and inaccurate. The observed inaccuracy was consistently present in all the experiments and was considered to be due to complications in the pitot tubes. This inaccuracy could best be seen in the angular location of the "cross-over" points. The cross-over point is the angular position at which the tangential velocity components are zero. The cross-over points are generally the same at all radii and they occurred at approximately 150° for the first and third pitot tubes (r/R = 0.451 and 0.735) in these experiments and for all the experimental radii in reference 1. However, the cross-over points for V_T/V from the second and fourth tubes of the present experiments were at approximately 120°. To correct the tangential velocity values measured with tubes two and four, the data for each tube were reduced by a constant amount necessary to bring the value of V_T/V at 150° to zero.

A second harmonic analysis was performed with the adjusted tangential velocity component values. The adjustment had no effect on the longitudinal velocity components and the harmonic content of the wake was unchanged. Presented herein are the wake survey data as measured and the results of the

harmonic analyses of the measured data. The circumferential mean of the tangential velocity components are presented in Figures 8, 14, and 20 for both adjusted and unadjusted data.

CONCLUSIONS

A new pitot tube rake was constructed to allow measurements to be taken at the propeller plane inside the kort nozzle. The rake performed well, but there were inaccuracies in the tangential velocity component measurements from the second and fourth tubes. The inaccuracies did not effect the determination of the longitudinal velocities or the harmonic analysis of the wake.

The data for the ARS-50 wake survey appears reasonable. The results of the wake survey of the ARS-50 hull without a nozzle or propeller compare well, within acceptable limits, to the results obtained in a previous wake survey performed on the ARS-46. The installation of a kort nozzle in the propeller plane increases the axial flow through the propeller plane by 6.5 percent. The presence of a propeller rotating at 150 rpm, ship scale, will increase the flow through the nozzle by an additional 18.8 percent. The presence of the nozzle and rotating propeller did not appreciably change the tangential component of the wake.

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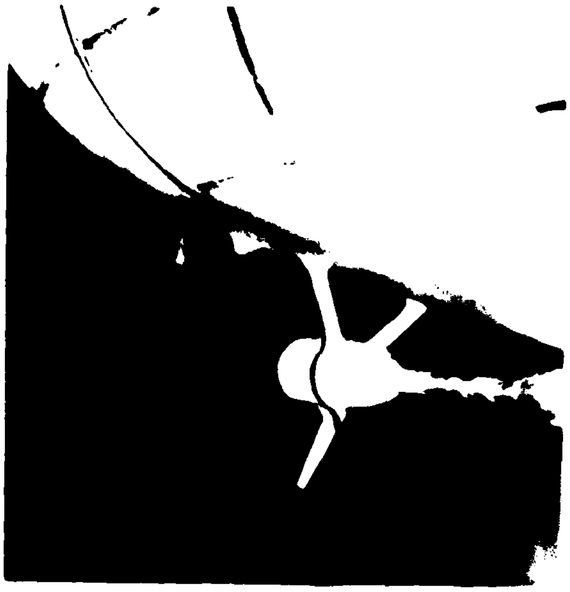
1. Anderson, K.J. and W.G. Day, "Predictions of Powering Performance Including Tow Rope Pull and the Results of Propeller Disk Wake Survey for the ARS-46 Salvage Ship Represented by Model 5391," DTNSRDC Report SPD-0957-01, (September 1980).

2. Grant, J.W. and A.C.M. Lin, "The Effects of Variations of Several Parameters on the Wake of the Propeller Plane for Series 60 - 0.60 C_B Models," Appendices A and D, DTNSRDC Report 3024, pp. 105, (June 1969).



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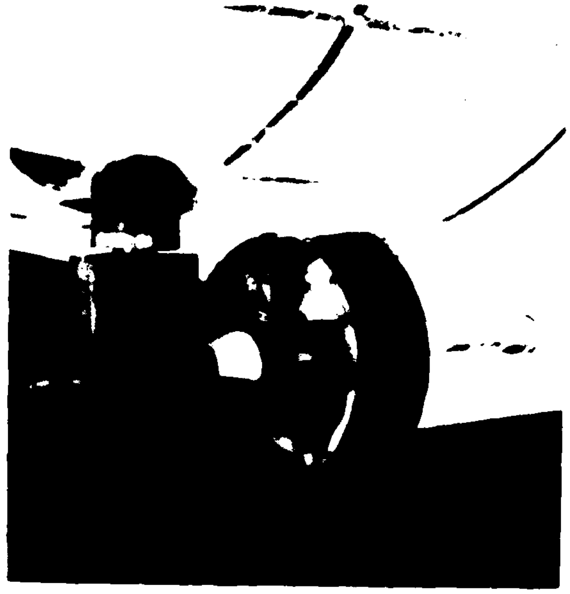

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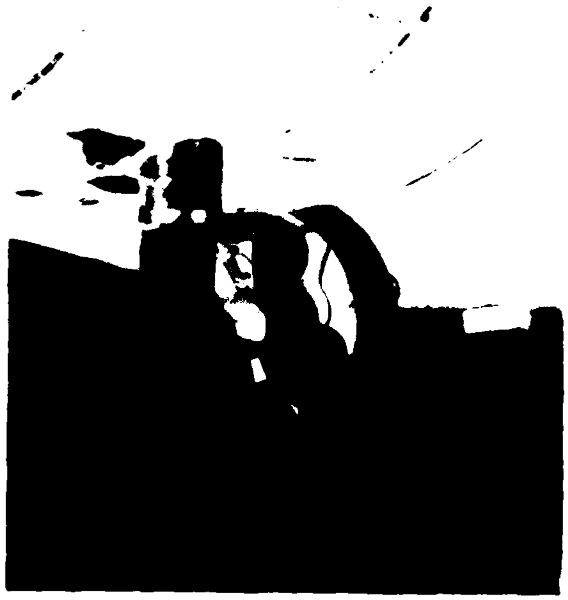

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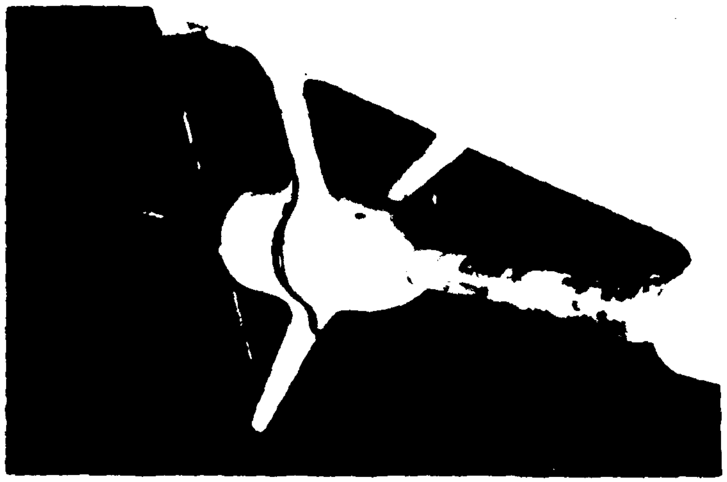
Figure 1 - Photographs showing the ARS-50 Nozzle with Propeller and Wake Survey Pitot Tube Rake



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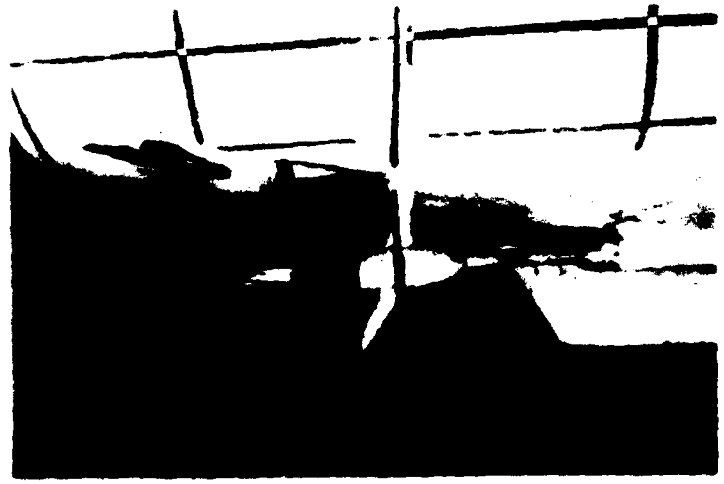

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PSD 7482-7-82

PSD 7479-7-82

Figure 2 - Photographs showing the ARS-50 Nozzle with Wake Survey Pitot Rake but without Propeller

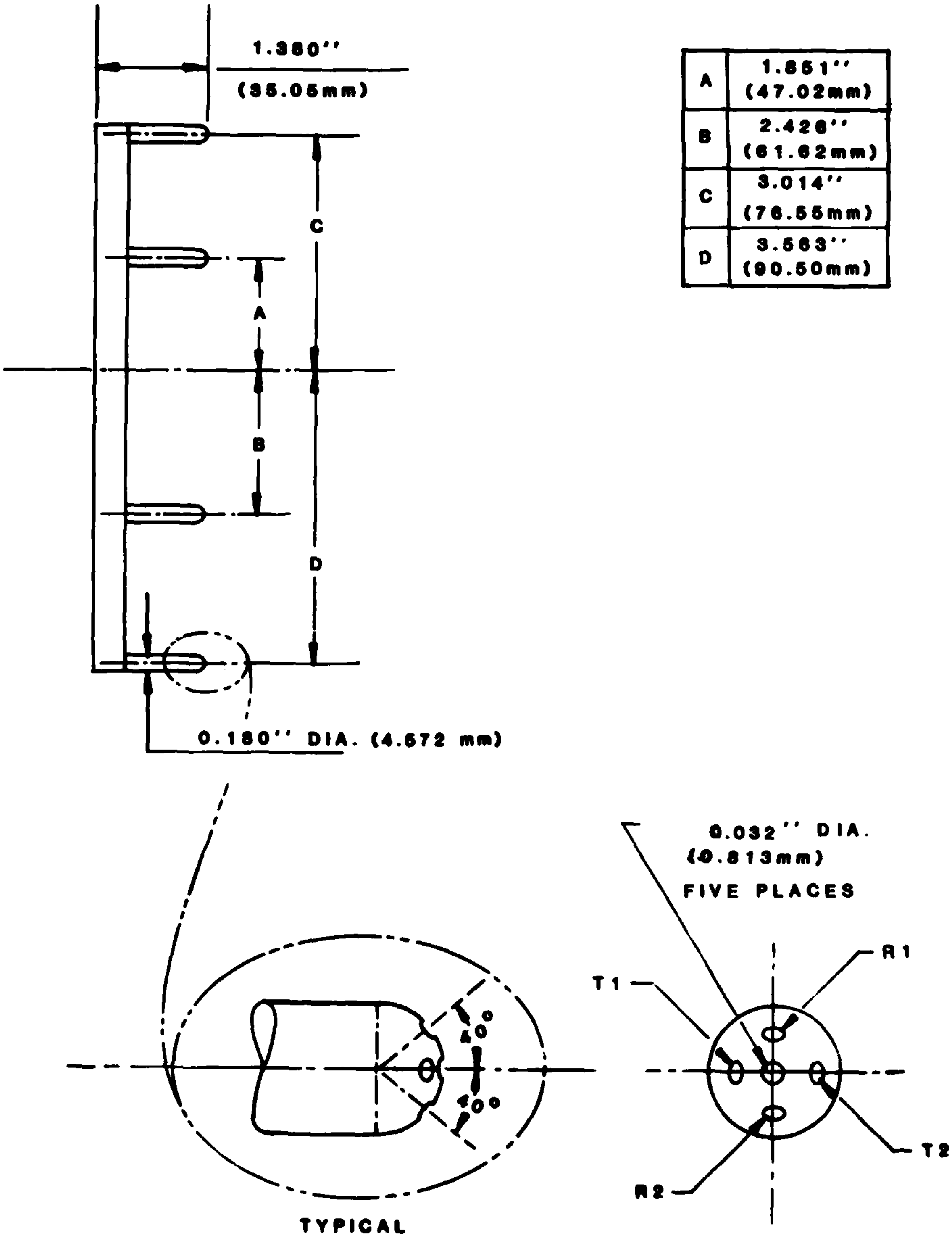


Figure 3 - Wake Survey Pitot Tube Rake Arrangement

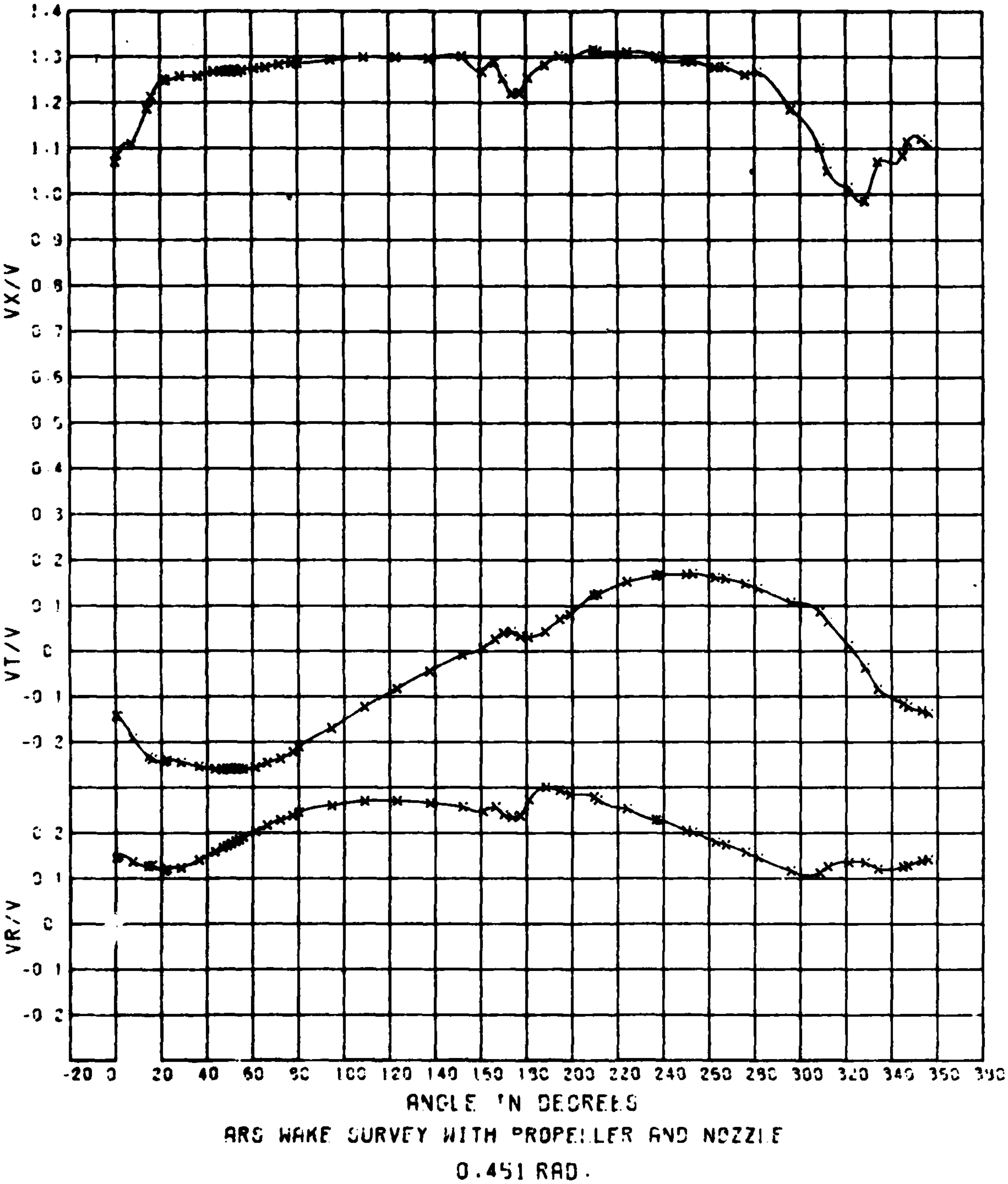


Figure 4 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.451 for the ARS-50 with Propeller and Nozzle

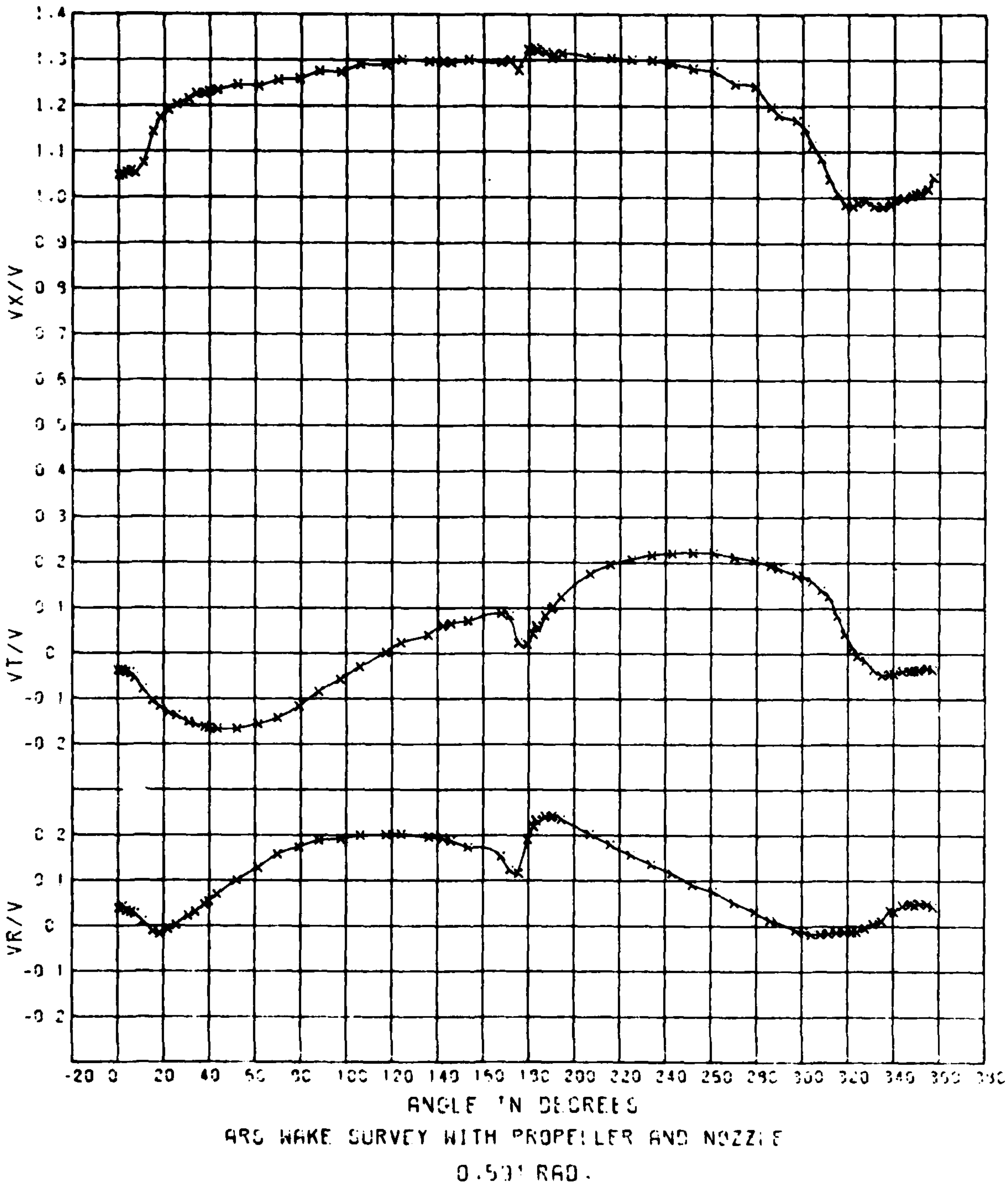


Figure 5 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.591 for the ARS-50 with Propeller and Nozzle

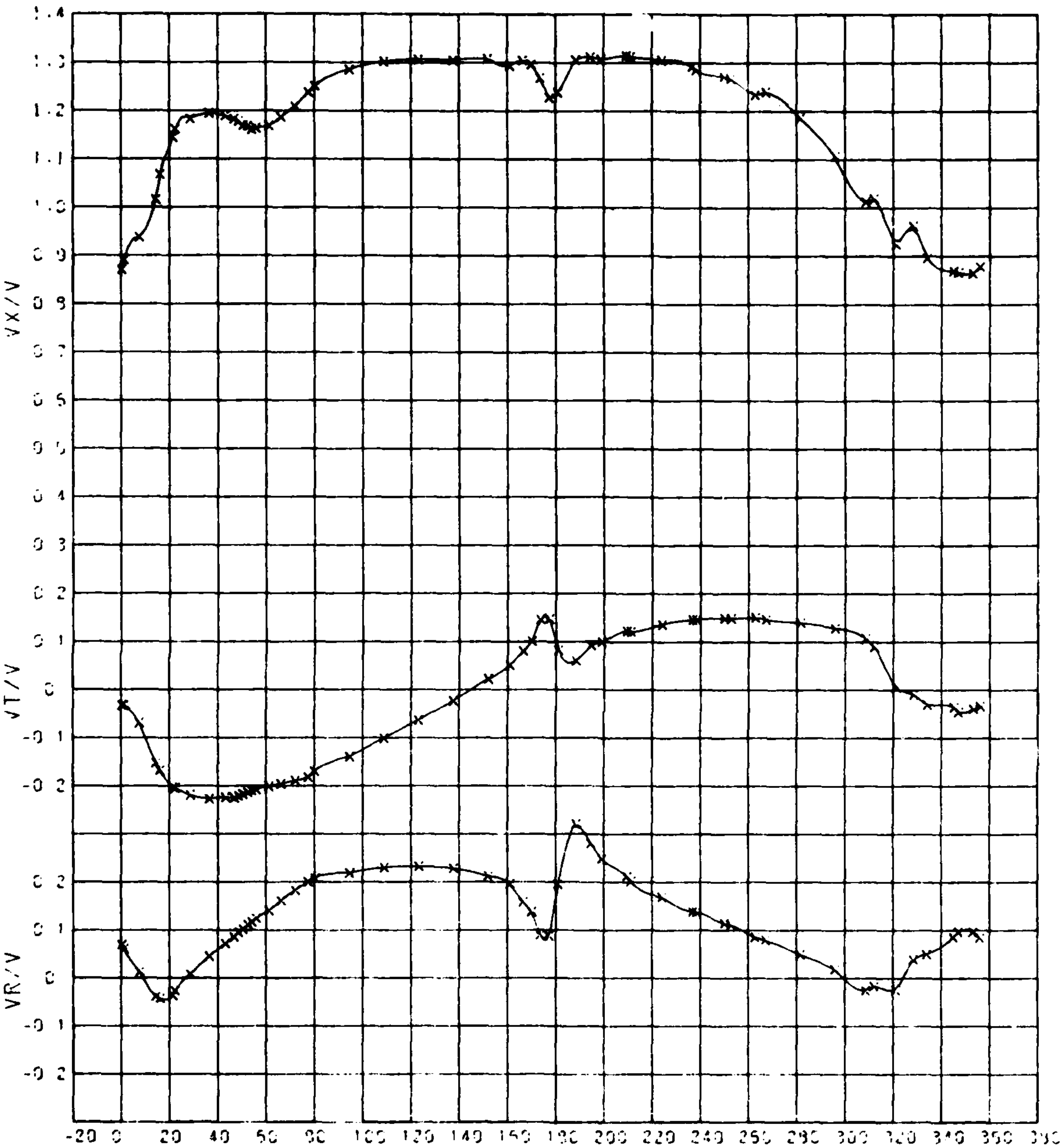


Figure 6 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.735 for the ARS-50 with Propeller and Nozzle

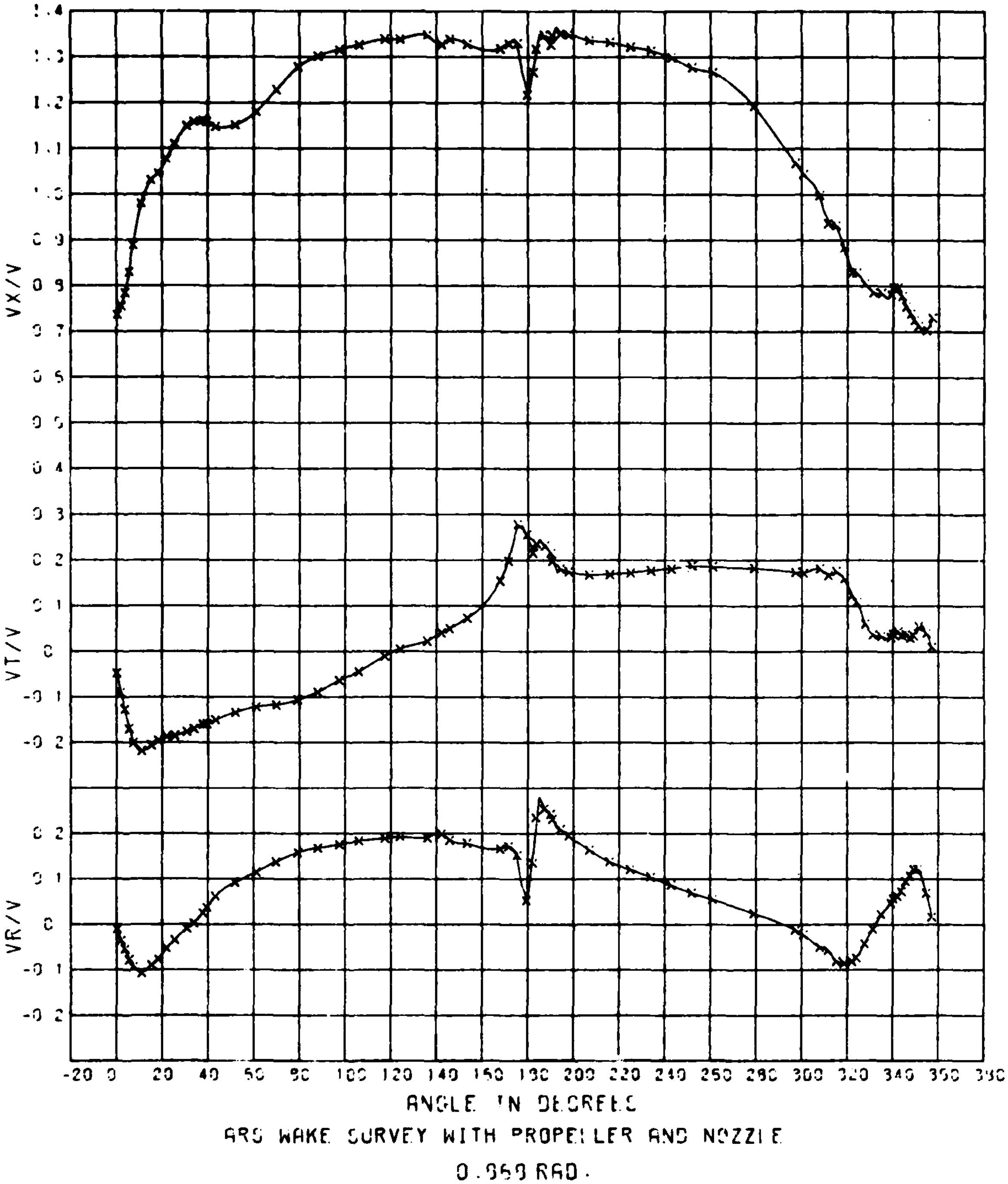


Figure 7 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.868 for the ARS-50 with Propeller and Nozzle

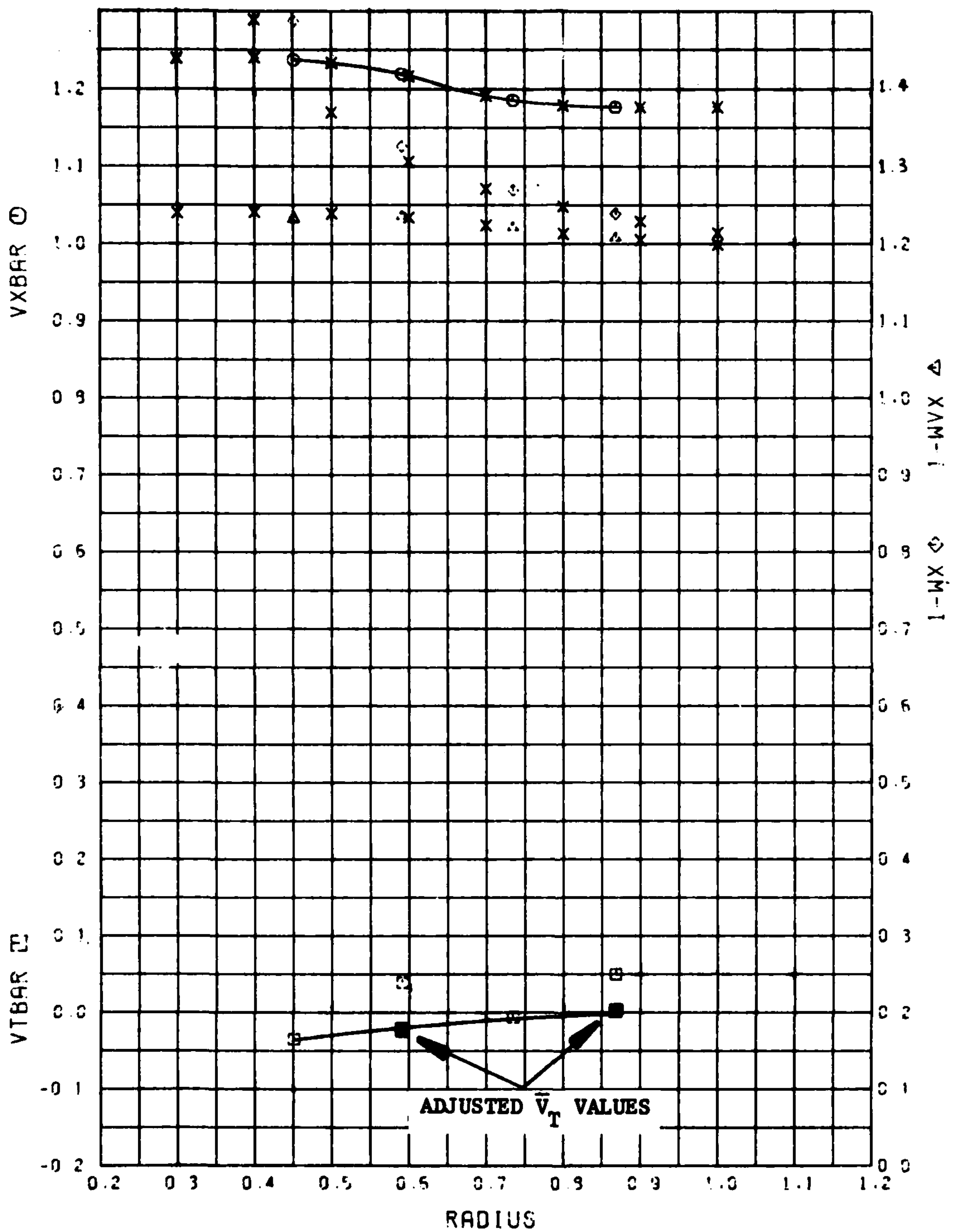


Figure 8 - Radial Distribution of the Mean Velocity Component Ratios for the ARS-50 with Propeller and Nozzle

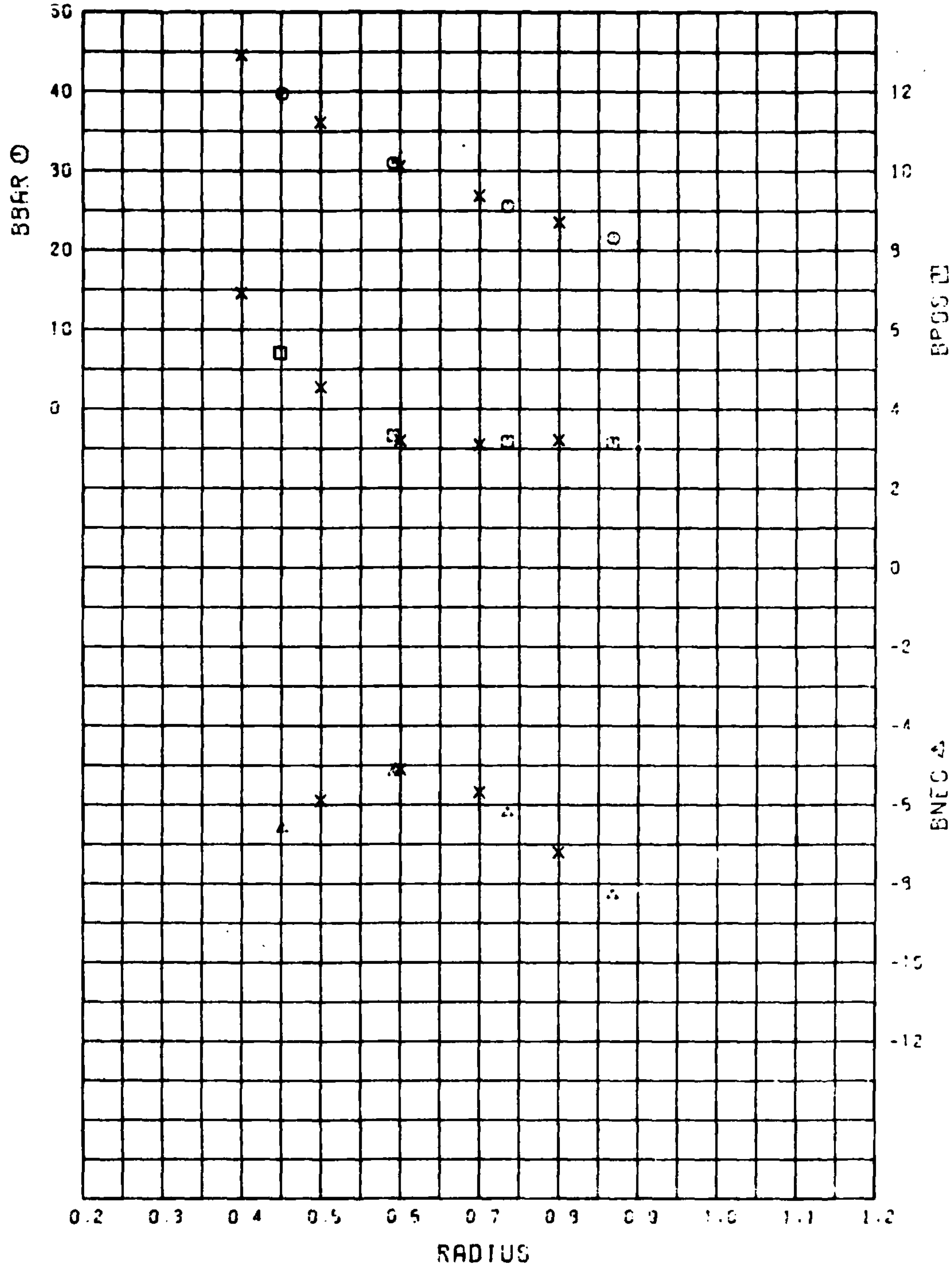


Figure 9 - Radial Distribution of the Mean Advance Angle and Advance Angle Variations for the ARS-50 with Propeller and Nozzle

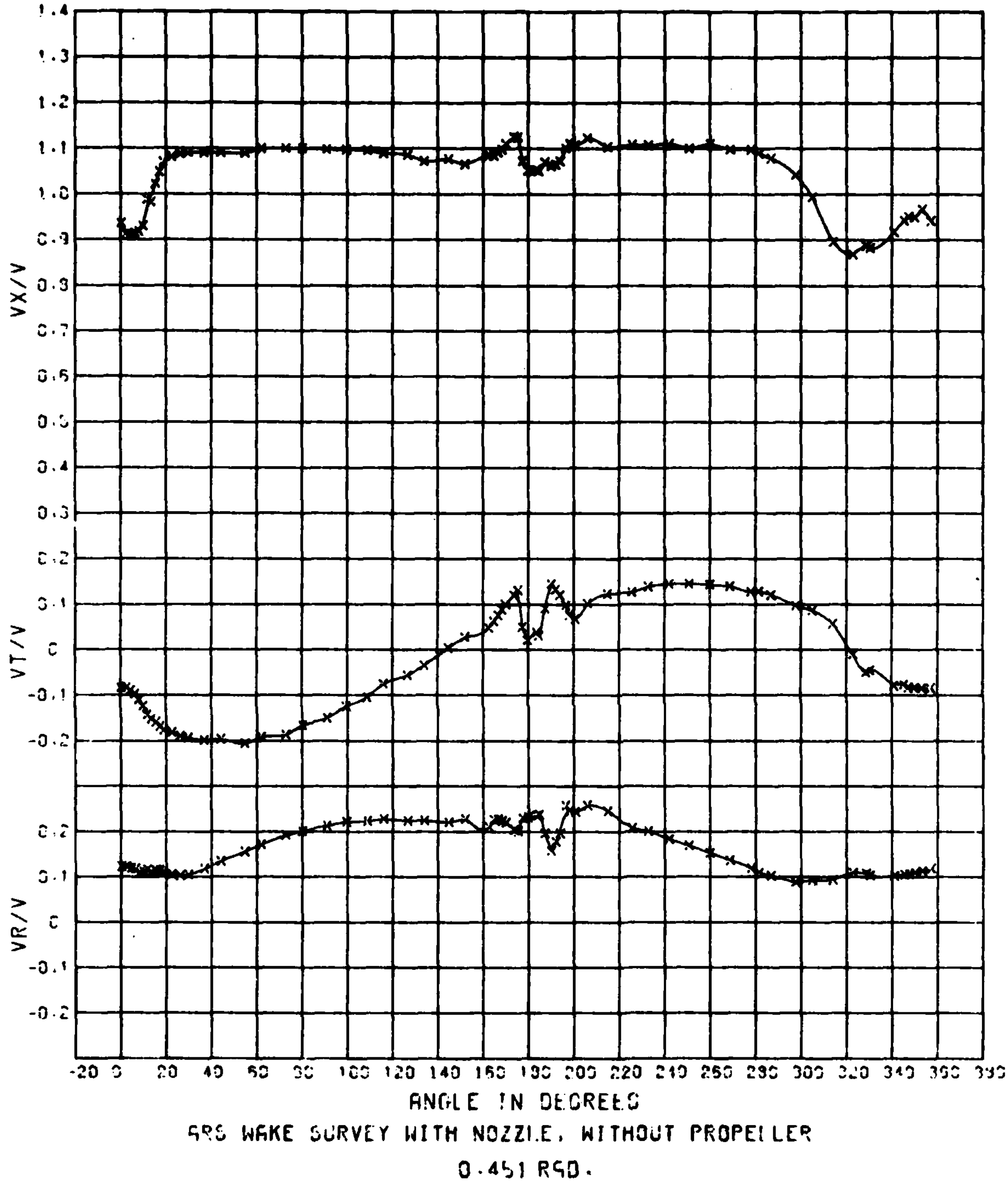


Figure 10 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.451 for the ARS-50 without Propeller, with Nozzle

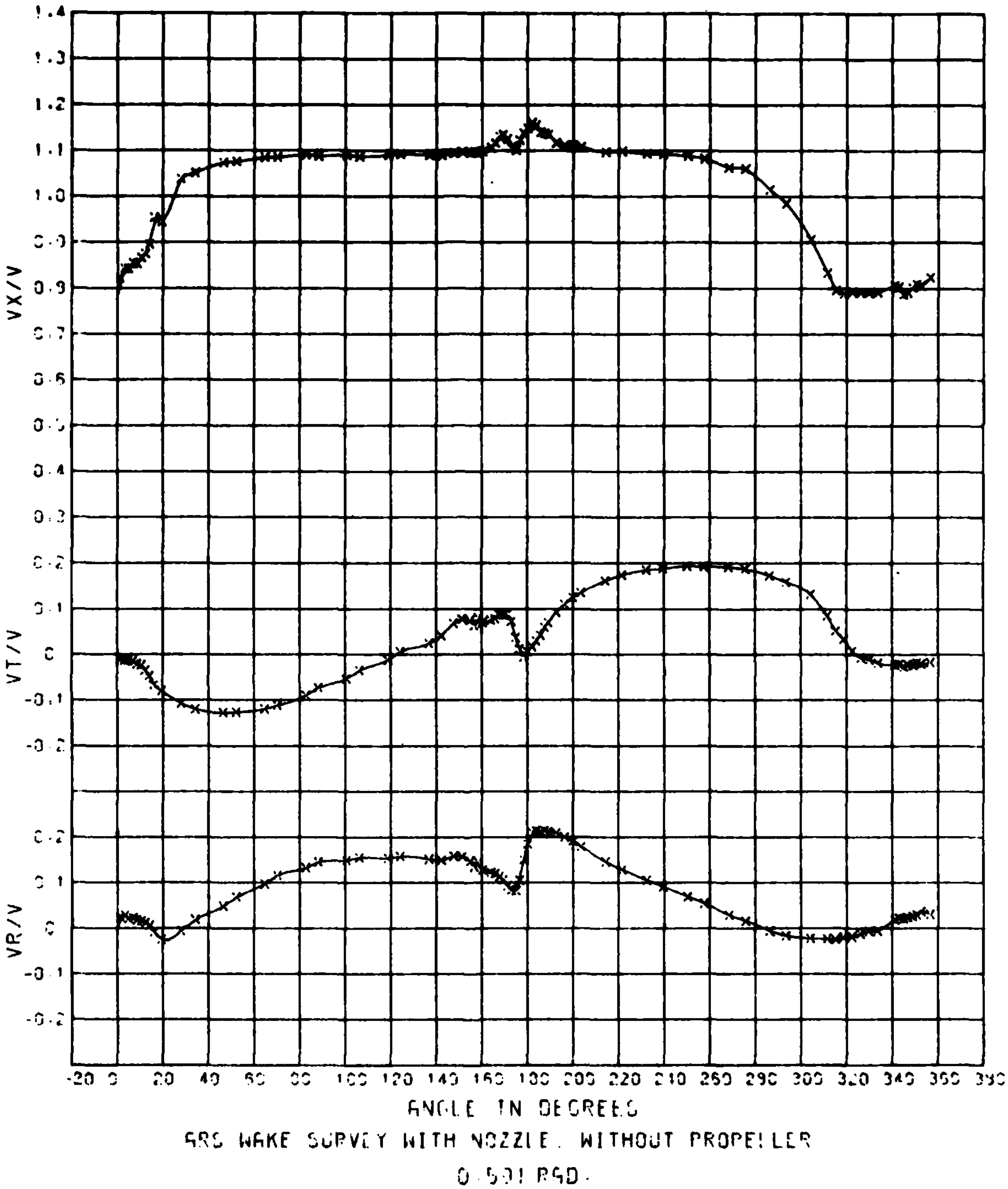


Figure 11 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.591 for the ARS-50 without Propeller, with Nozzle

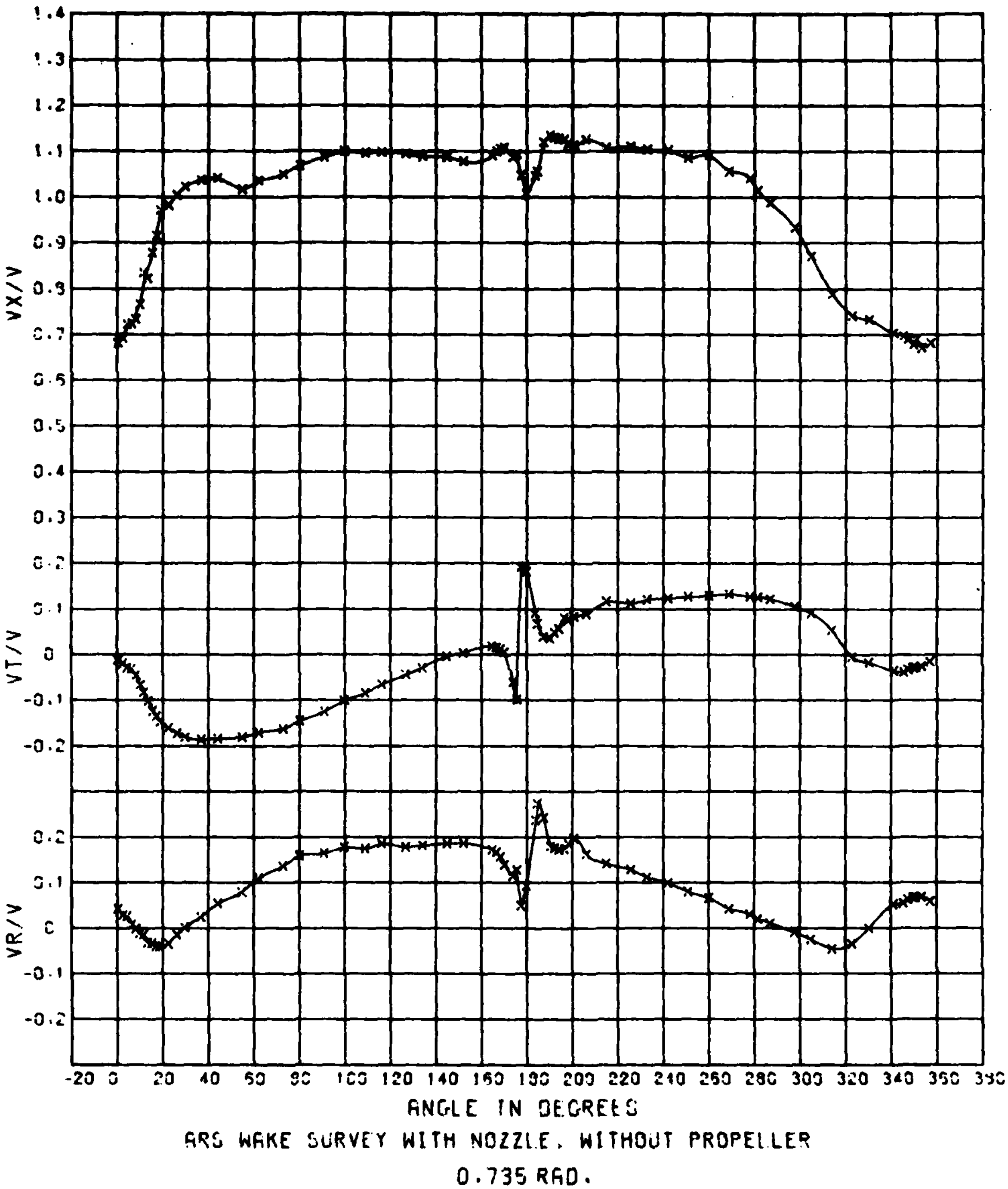


Figure 12 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.735 for the ARS-50 without Propeller, with Nozzle

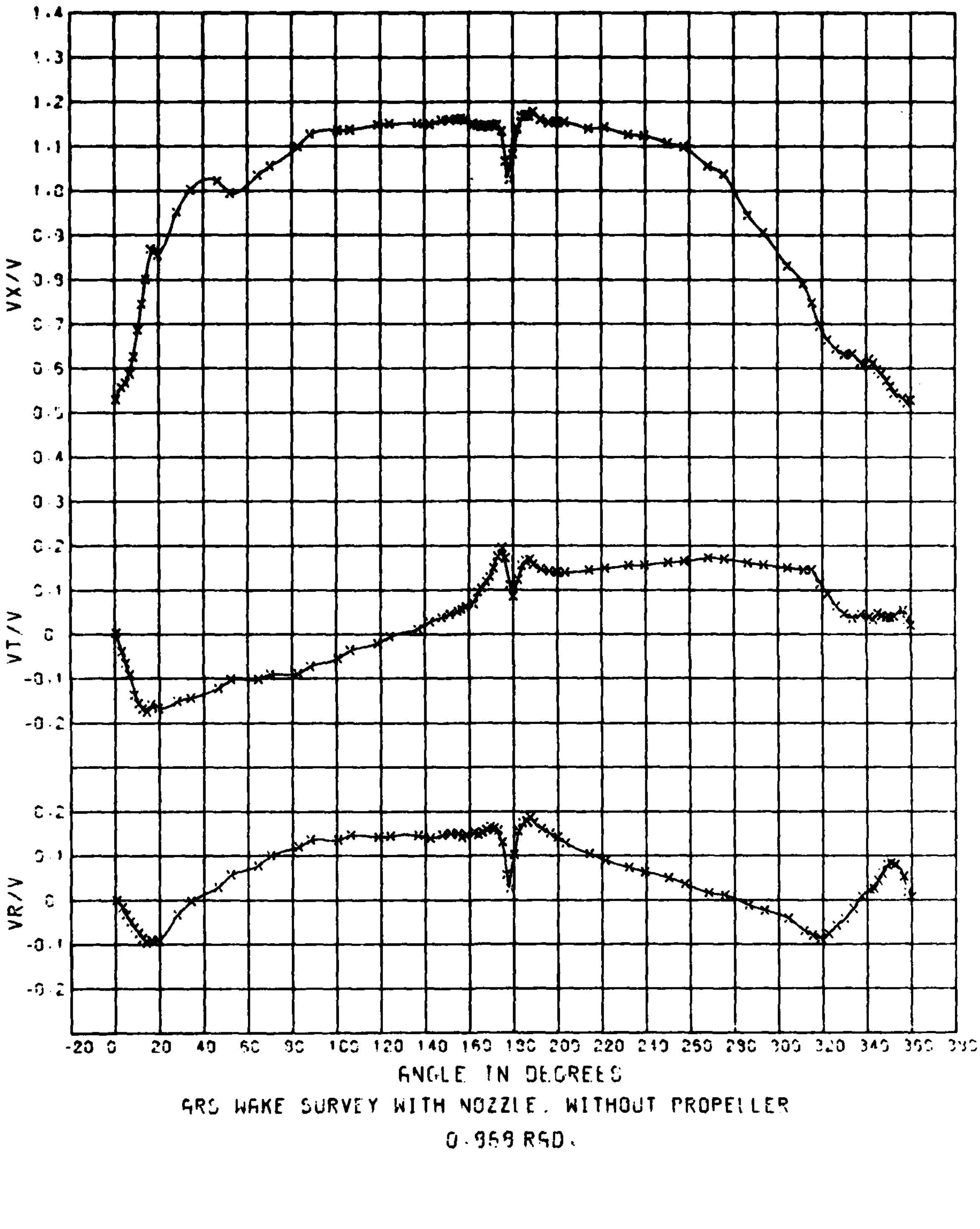


Figure 13 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.868 for the ARS-50 without Propeller, with Nozzle

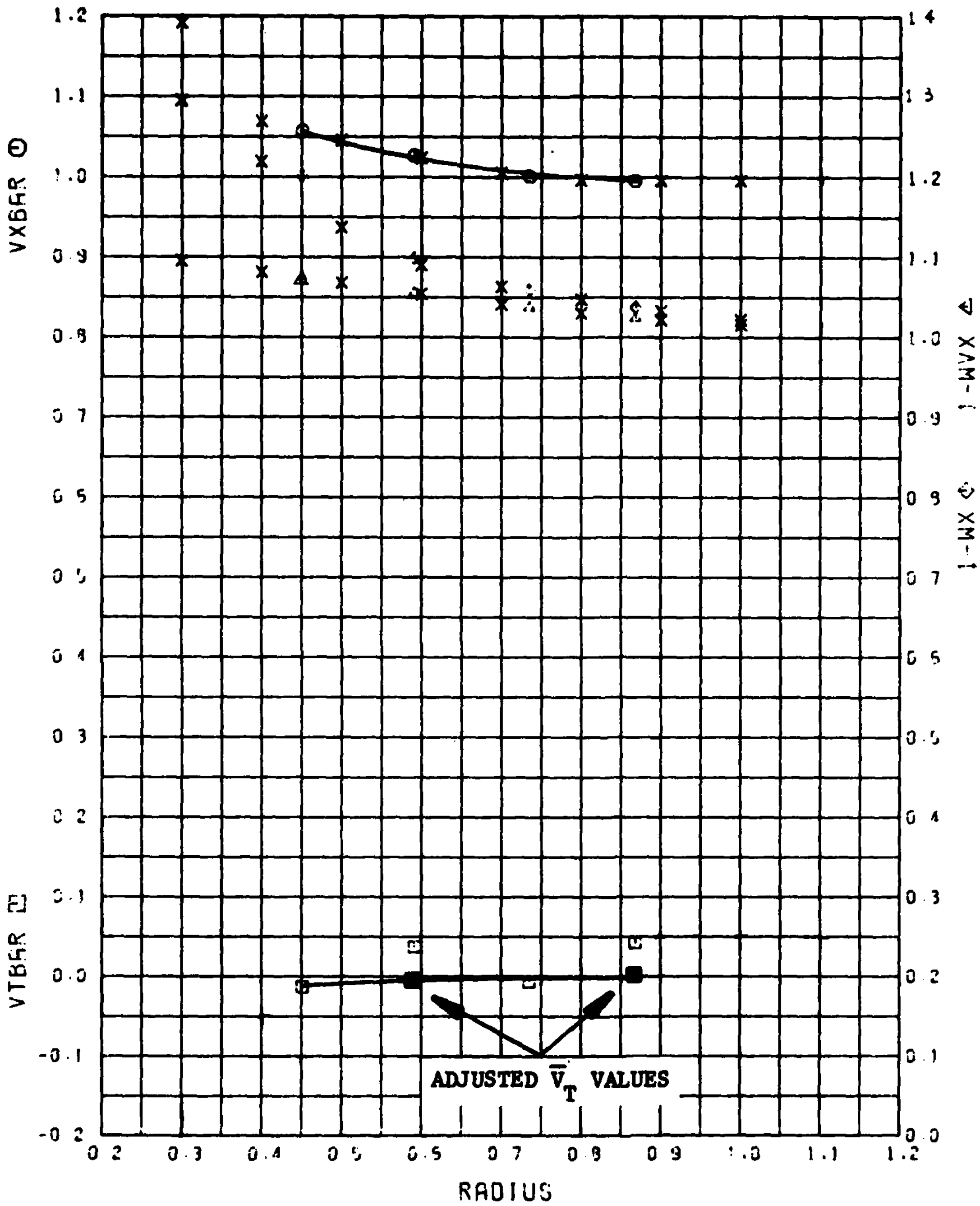


Figure 14 - Radial Distribution of the Mean Velocity Component Ratios for the ARS-50 without Propeller, with Nozzle

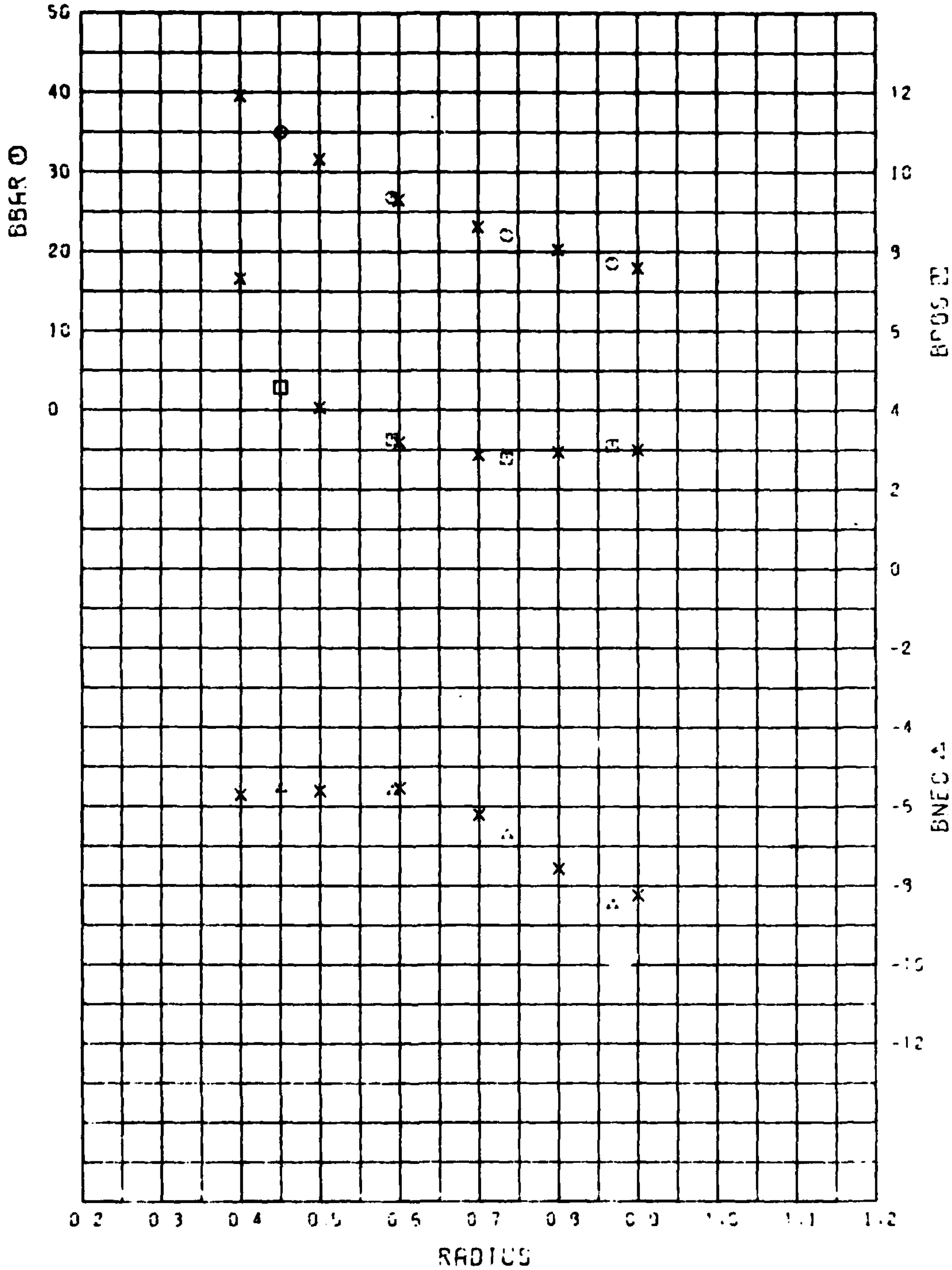


Figure 15 - Radial Distribution of the Mean Advance Angle and Advance Angle Variations for the ARS-50 without Propeller, with Nozzle

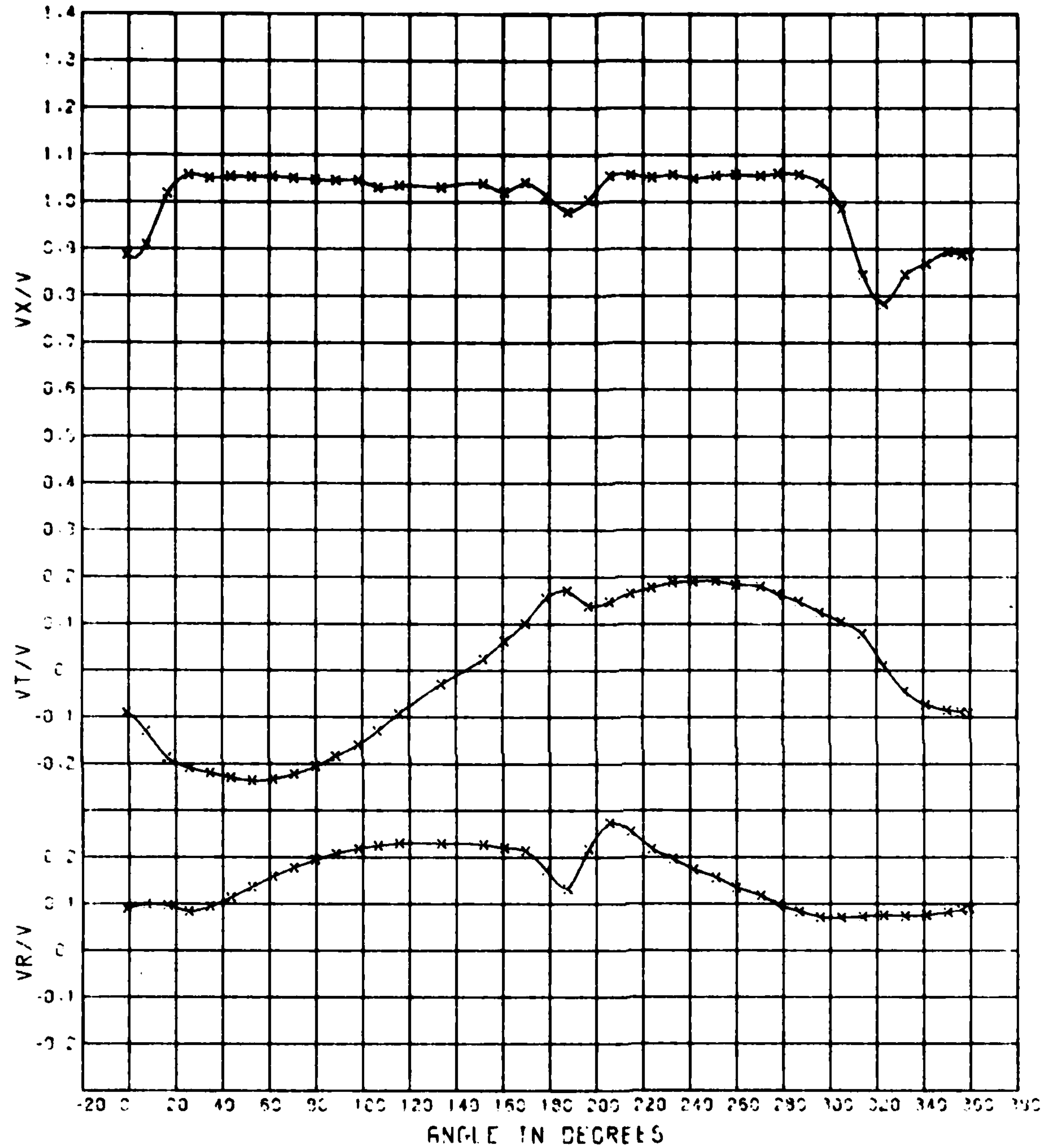


Figure 16 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.451 for the ARS-50 without Nozzle or Propeller

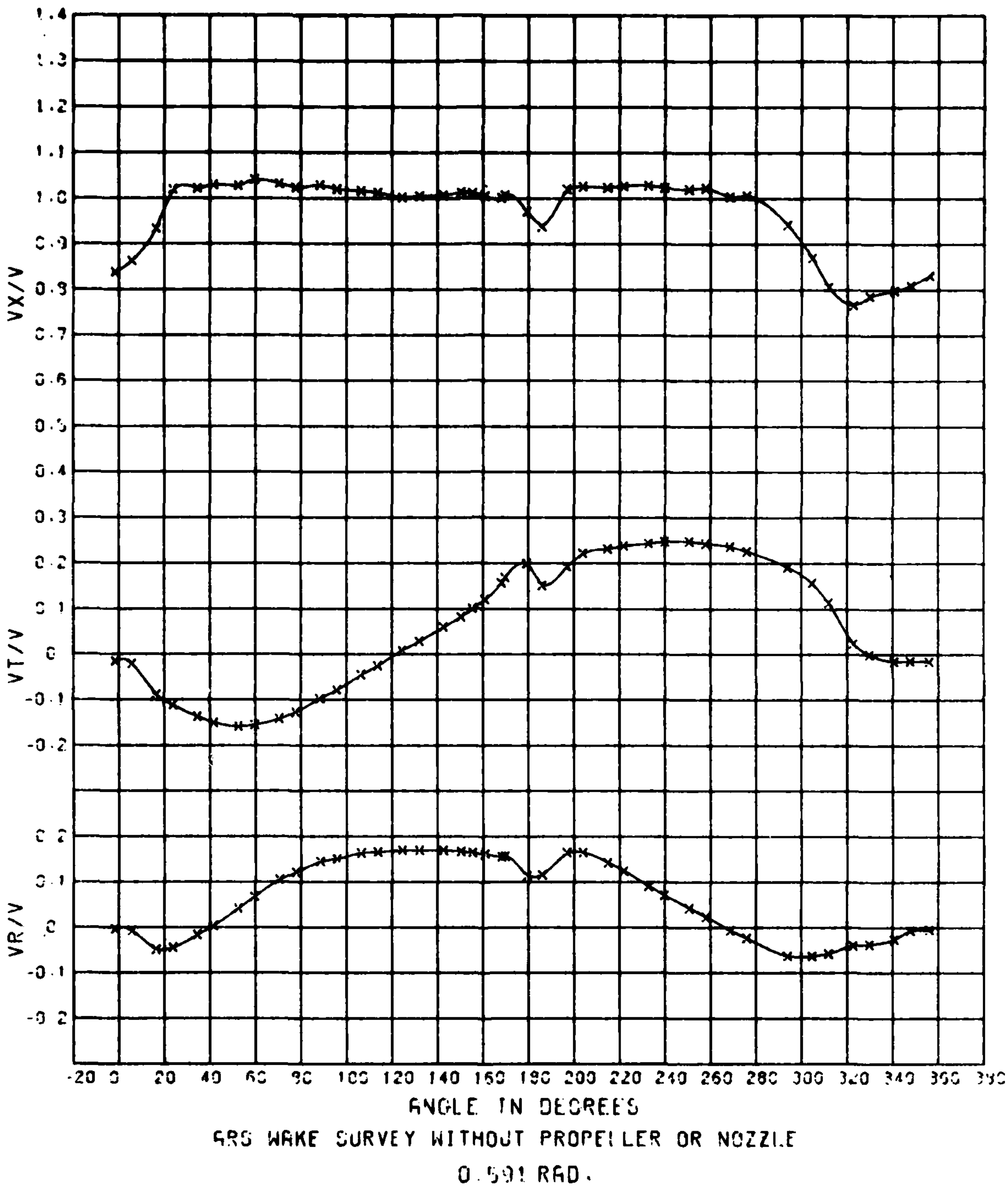


Figure 17 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.591 for the ARS-50 without Nozzle or Propeller

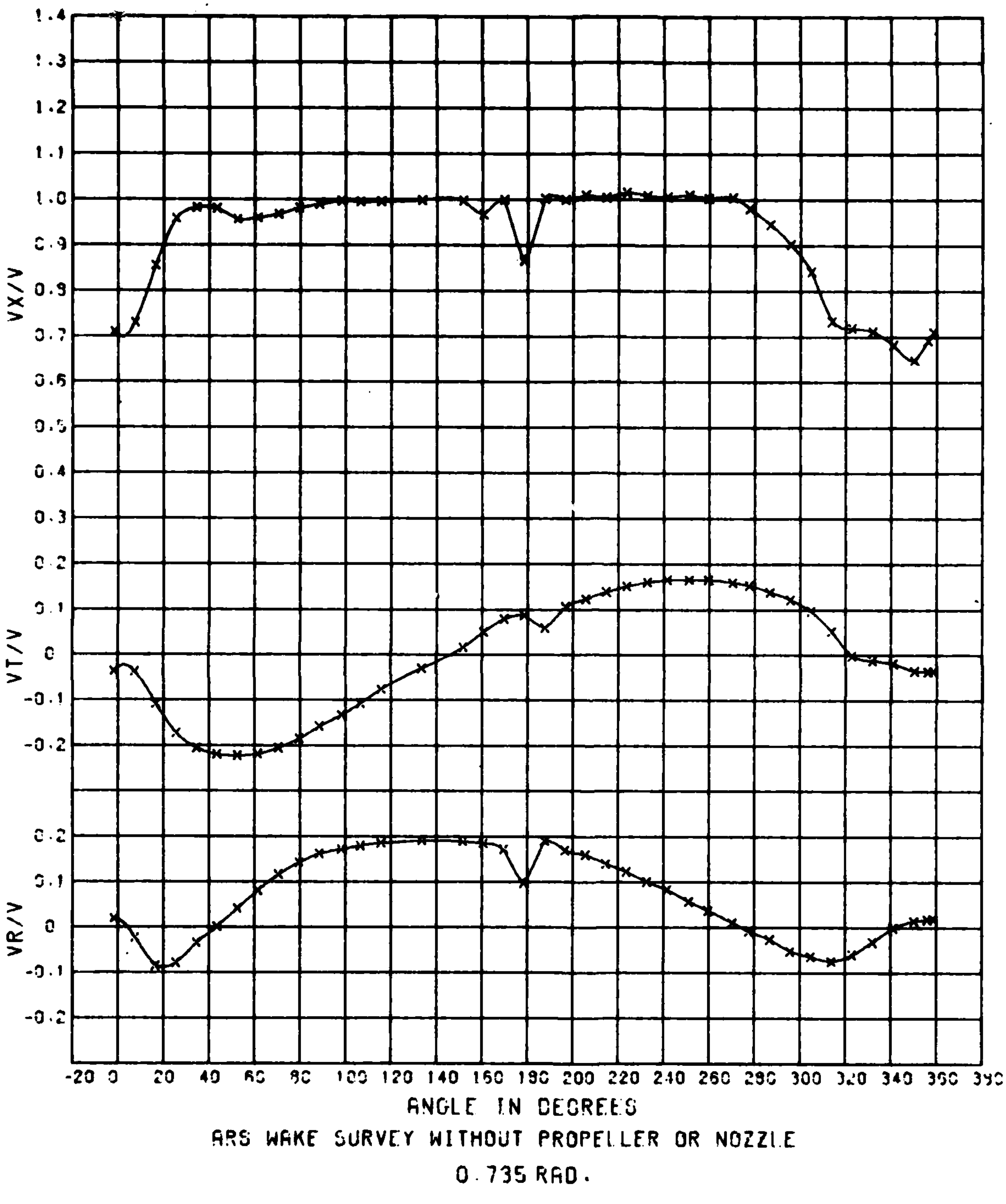


Figure 18- Circumferential Distribution of Velocity Component Ratios at r/R = 0.735 for the ARS-50 without Nozzle or Propeller

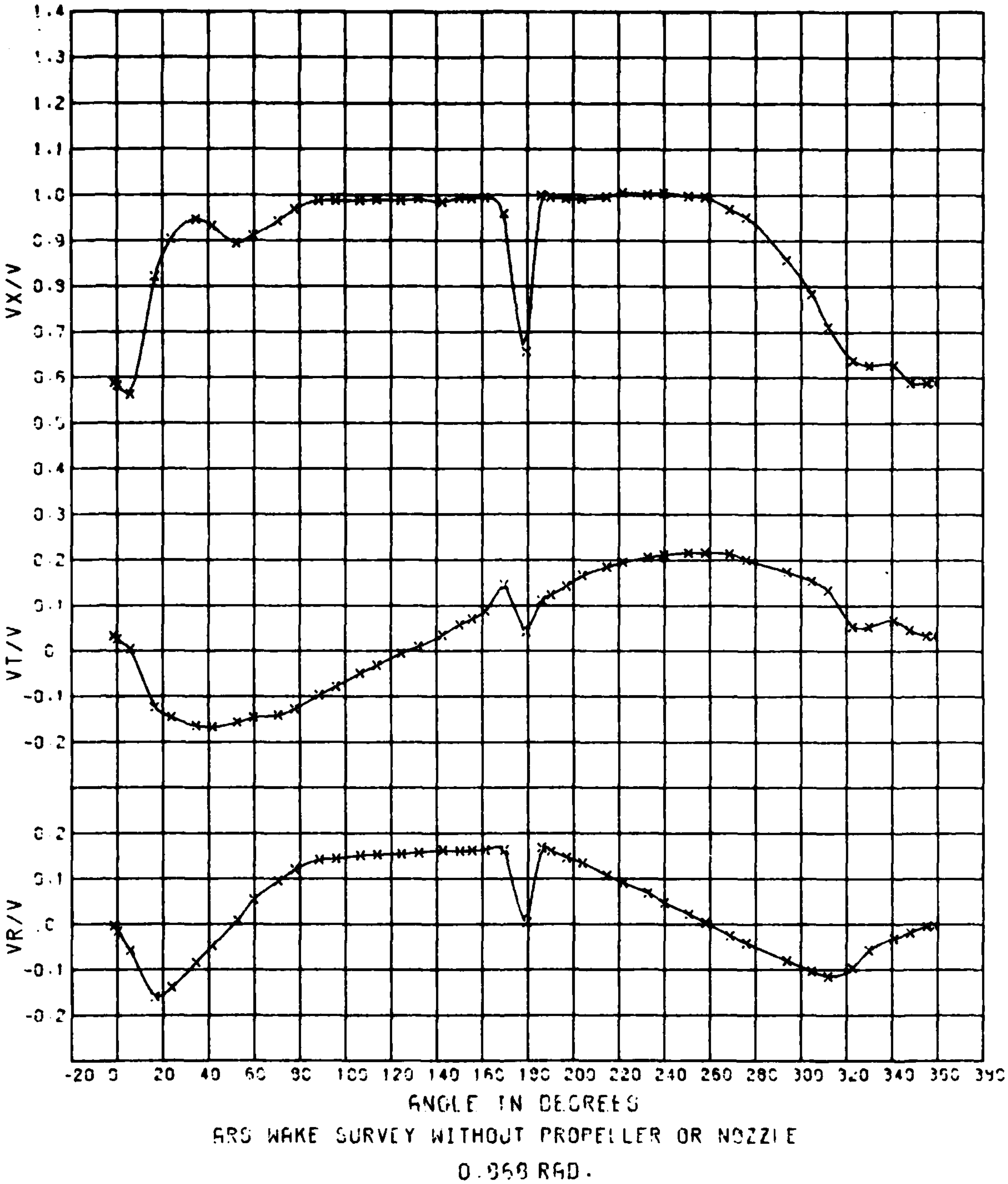


Figure 19 - Circumferential Distribution of Velocity Component Ratios at r/R = 0.868 for the ARS-50 without Nozzle or Propeller

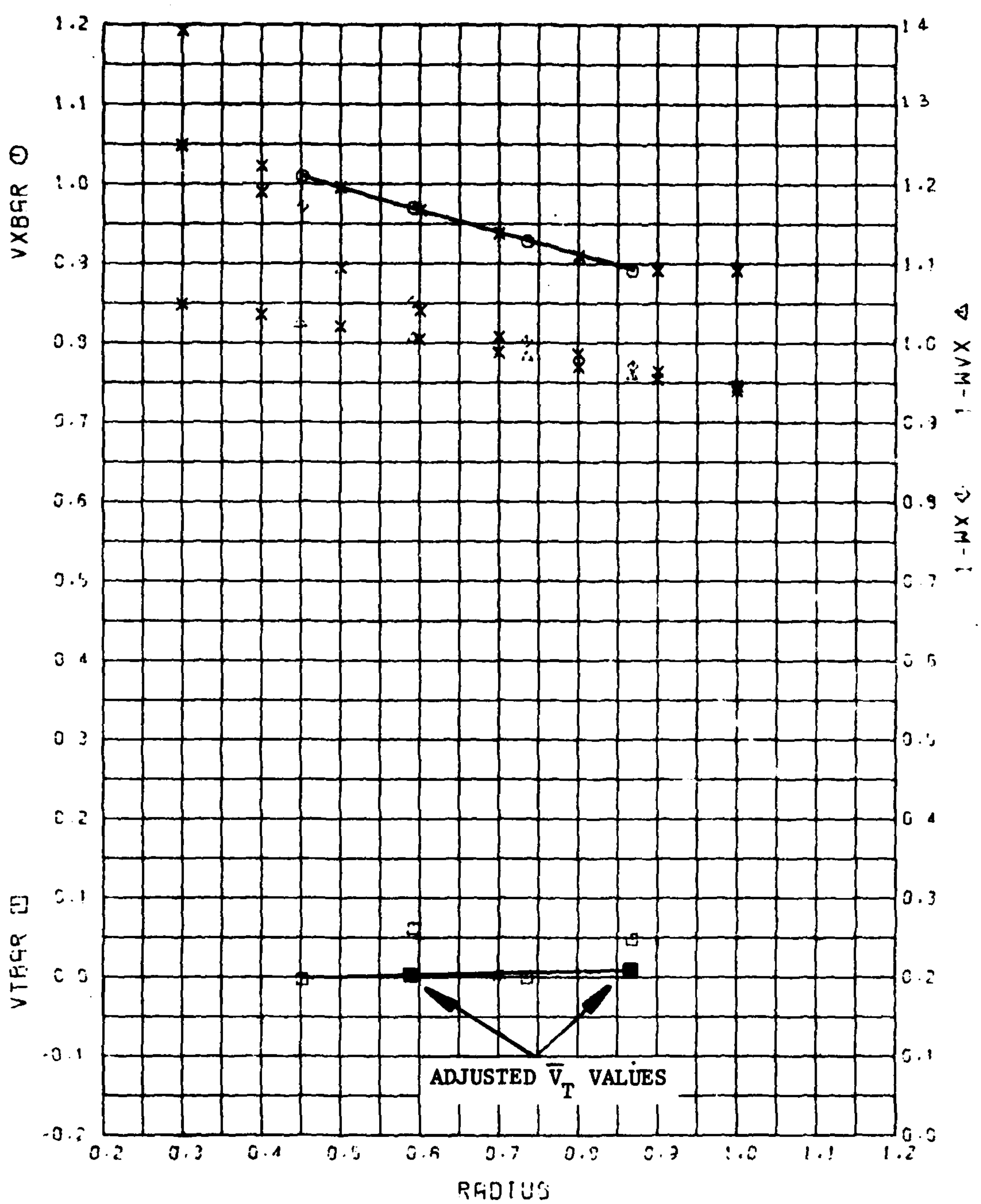


Figure 20 - Radial Distribution of the Mean Velocity Component Ratios for the ARS-50 without Nozzle or Propeller

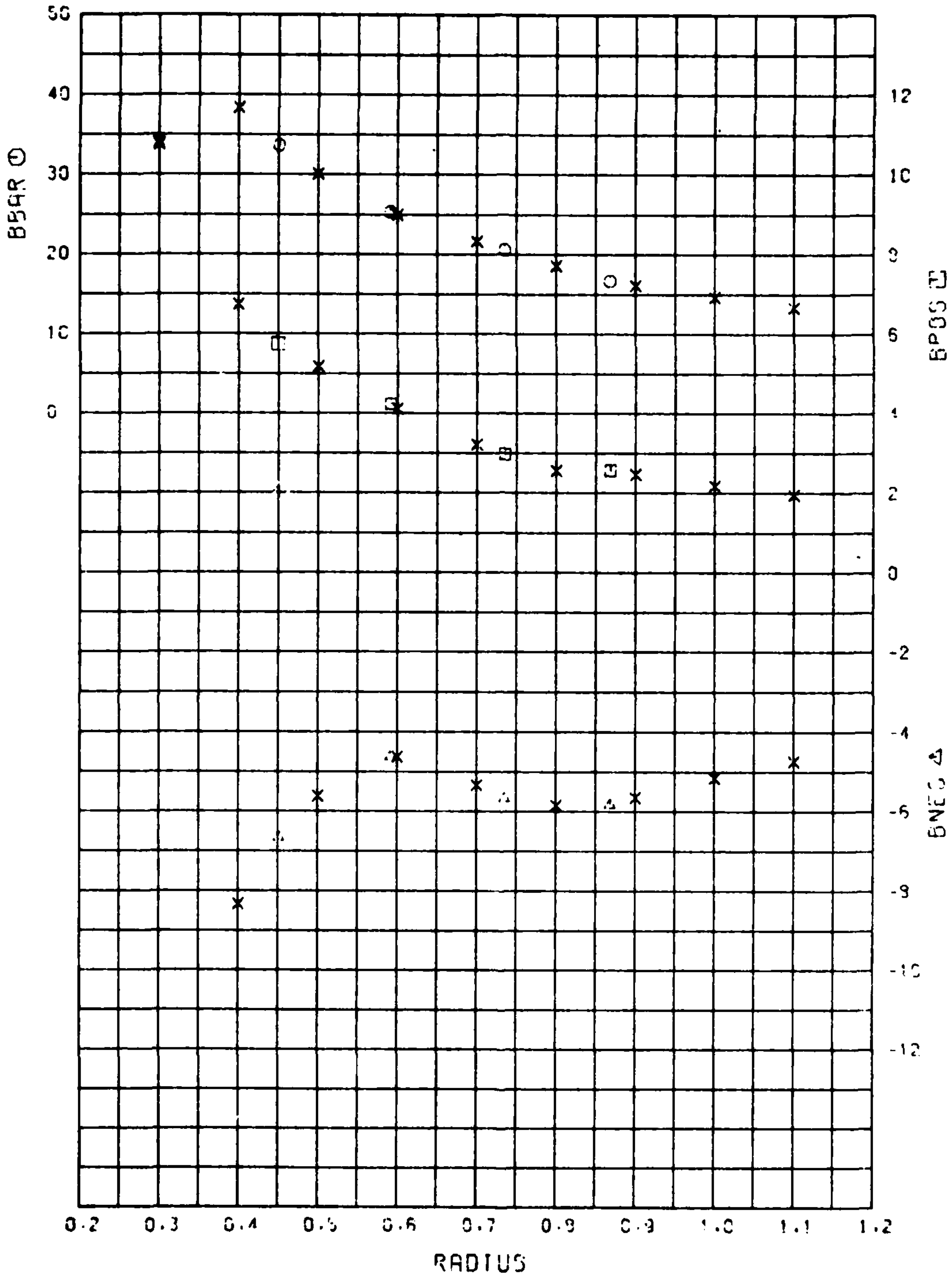
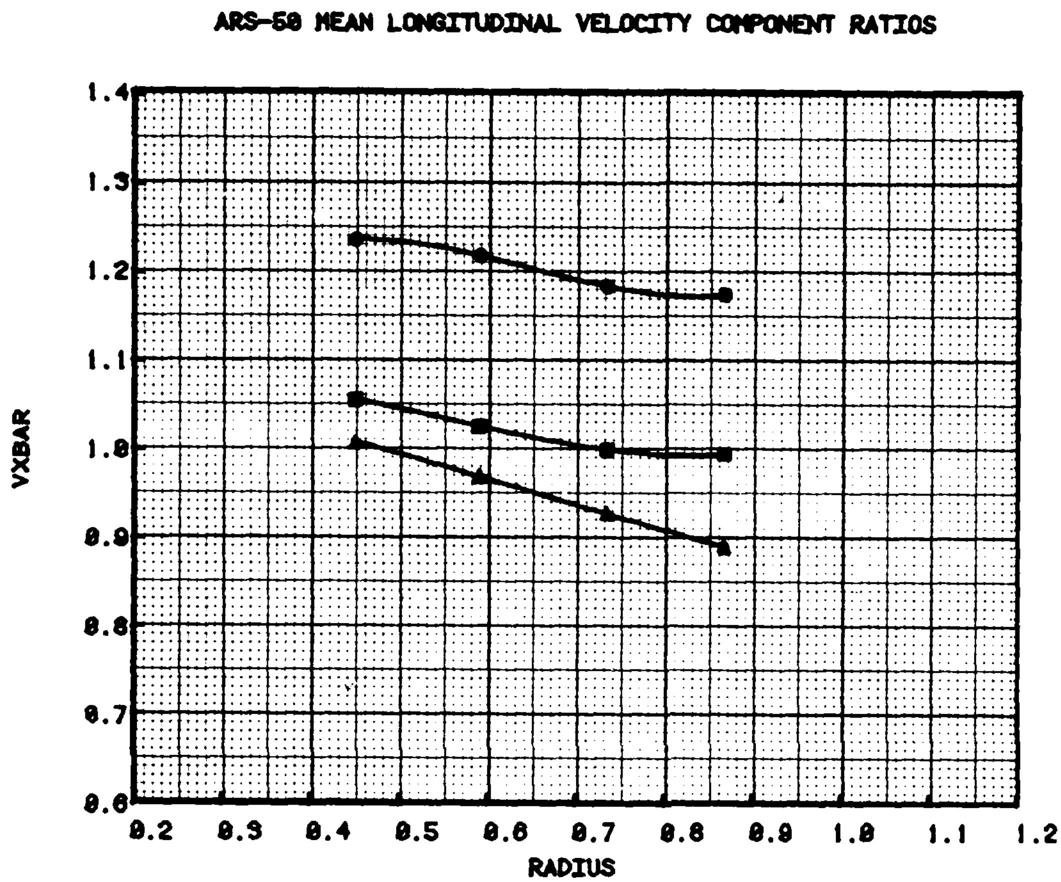


Figure 21 - Radial Distribution of the Mean Advance Angle and Advance Angle Variations for the ARS-50 without Nozzle or Propeller



O WITH PROPELLER AND NOZZLE
□ WITHOUT PROPELLER, WITH NOZZLE
Δ WITHOUT PROPELLER OR NOZZLE

Figure 22 - Comparison Plot of the Radial Distribution of the Mean Longitudinal Valocity Component Ratio vs. Fraction of Propeller Radius for the ARS-50 in the Three Experimental Conditions

TABLE 1 - EXPERIMENTAL WAKE SURVEY DATA FOR THE ARS-50 WITH PROPELLER AND NOZZLE

	RADIUS = .451		
ANGLE	VX/V	VT/V	VR/V
.1	1.063	-.145	.140
.5	1.078	-.141	.149
1.1	1.086	-.144	.149
7.1	1.092	-.184	.133
7.9	1.126	-.200	.140
14.3	1.187	-.232	.127
16.1	1.213	-.237	.129
21.3	1.261	-.244	.120
21.5	1.241	-.244	.115
22.4	1.250	-.241	.121
28.5	1.265	-.245	.124
28.7	1.251	-.245	.122
36.0	1.256	-.253	.137
36.9	1.260	-.253	.146
43.4	1.268	-.260	.158
46.7	1.268	-.261	.167
48.6	1.268	-.260	.171
50.4	1.270	-.261	.175
52.3	1.270	-.259	.181
54.0	1.267	-.259	.184
55.8	1.271	-.260	.190
61.2	1.274	-.256	.203
65.6	1.275	-.244	.217
66.8	1.278	-.248	.217
72.1	1.283	-.237	.228
77.4	1.287	-.222	.239
80.1	1.286	-.211	.245
94.5	1.293	-.170	.260
108.8	1.299	-.123	.270
123.1	1.299	-.082	.271
137.5	1.296	-.044	.266
151.9	1.301	-.009	.257
161.0	1.267	.007	.247
166.3	1.267	.023	.246
166.3	1.310	.030	.267
169.9	1.252	.040	.239
173.6	1.219	.043	.234
177.3	1.221	.033	.238
180.7	1.258	.036	.278
181.0	1.250	.026	.268
188.4	1.282	.043	.300
193.8	1.279	.060	.293
195.2	1.325	.080	.293
198.6	1.313	.089	.284
199.4	1.281	.073	.285
209.5	1.316	.123	.279
211.2	1.313	.126	.272
224.0	1.310	.153	.254
224.1	1.311	.151	.251
236.7	1.301	.166	.228
238.3	1.293	.168	.228
249.9	1.290	.168	.205
252.7	1.290	.170	.201
262.8	1.278	.162	.180
267.2	1.279	.159	.174
275.9	1.260	.148	.157
281.5	1.267	.138	.145
295.8	1.158	.102	.117
295.9	1.212	.112	.116
308.5	1.102	.087	.112

	RADIUS = .451		
ANGLE	VX/V	VT/V	VR/V
312.0	1.050	.064	.126
321.1	1.016	.013	.136
328.4	.985	-.036	.135
333.9	1.071	-.084	.120
345.0	1.084	-.115	.126
347.0	1.115	-.122	.128
352.5	1.120	-.129	.135
353.6	1.123	-.134	.143
356.0	1.109	-.137	.142
359.8	1.037	-.141	.140

	RADIUS = .591		
ANGLE	VX/V	VT/V	VR/V
.2	1.048	-.038	.039
1.9	1.050	-.037	.043
3.7	1.056	-.041	.034
5.5	1.058	-.043	.031
7.3	1.053	-.053	.027
10.9	1.075	-.079	.009
14.5	1.111	-.104	-.008
15.9	1.175	-.106	-.013
18.2	1.175	-.117	-.017
21.8	1.191	-.129	-.007
25.4	1.203	-.137	.002
30.7	1.215	-.151	.023
33.8	1.227	-.156	.031
37.8	1.227	-.162	.047
39.6	1.231	-.165	.054
43.3	1.234	-.166	.069
51.9	1.246	-.167	.100
61.2	1.243	-.156	.129
69.8	1.256	-.142	.158
79.3	1.259	-.117	.174
87.9	1.275	-.084	.188
97.4	1.274	-.057	.192
106.0	1.291	-.030	.200
117.3	1.290	.001	.201
124.0	1.301	.024	.202
136.0	1.297	.040	.196
142.1	1.297	.061	.194
145.3	1.295	.062	.189
146.1	1.296	.069	.186
153.3	1.300	.071	.173
167.5	1.281	.069	.157
168.0	1.309	.087	.150
171.5	1.300	.083	.124
175.4	1.278	.023	.116
179.1	1.323	.011	.174
179.8	1.324	.029	.207
181.5	1.321	.040	.219
182.9	1.332	.043	.218
182.9	1.324	.069	.237
183.3	1.320	.054	[illegible]
183.4	1.321	.057	.231
187.1	1.318	.083	.242
189.6	1.291	.105	.238
190.3	1.319	.092	.241
190.6	1.313	.103	.243
194.2	1.315	.124	.235
206.8	1.304	.174	.202

TABLE 1 - CONTINUED

RADIUS = .591

ANGLE	VX/V	VT/V	VR/V
206.8	1.310	.176	.203
215.8	1.304	.195	.179
224.9	1.301	.207	.157
233.8	1.300	.216	.135
233.8	1.299	.217	.136
242.8	1.293	.220	.116
251.8	1.282	.223	.091
260.9	1.275	.221	.076
270.1	1.248	.213	.051
279.0	1.242	.205	.031
286.0	1.198	.194	.013
289.2	1.181	.189	.009
297.1	1.169	.174	-.009
300.7	1.151	.170	-.011
304.0	1.114	.160	-.018
308.0	1.084	.139	-.018
311.6	1.039	.126	-.016
315.1	1.009	.083	-.013
318.6	.983	.044	-.012
321.9	.983	.018	-.014
322.1	.979	.010	-.012
324.0	.989	-.006	-.013
327.6	.993	-.016	-.004
331.2	.982	-.035	.006
334.9	.980	-.047	.011
338.5	.985	-.045	.034
340.2	.994	-.045	.031
343.9	.999	-.038	.046
347.6	1.005	-.038	.049
349.2	1.008	-.037	.047
351.1	1.012	-.037	.051
354.8	1.018	-.032	.048
356.5	1.034	-.034	.043
357.9	1.054	-.036	.042
358.3	1.044	-.036	.045

RADIUS = .735

ANGLE	VX/V	VT/V	VR/V
.1	.874	-.033	.068
.5	.867	-.032	.070
1.1	.890	-.033	.060
7.1	.925	-.066	.021
7.9	.950	-.074	.004
14.3	1.015	-.153	-.039
16.1	1.068	-.168	-.043
21.3	1.161	-.204	-.035
21.5	1.128	-.202	-.039
22.4	1.162	-.205	-.027
28.5	1.195	-.222	.007
28.7	1.172	-.217	.008
36.0	1.193	-.226	.041
36.9	1.195	-.229	.049
43.1	1.190	-.223	.072
46.7	1.183	-.225	.085
48.6	1.179	-.222	.095
50.4	1.169	-.218	.101
52.3	1.169	-.214	.111
54.0	1.161	-.210	.116
55.8	1.164	-.208	.124
61.2	1.168	-.201	.140

RADIUS = .735

ANGLE	VX/V	VT/V	VR/V
65.6	1.188	-.196	.160
66.8	1.186	-.197	.162
72.1	1.209	-.190	.182
77.4	1.239	-.182	.200
80.1	1.251	-.170	.204
94.5	1.285	-.139	.218
108.8	1.302	-.101	.230
123.1	1.307	-.064	.232
137.5	1.305	-.024	.228
151.9	1.308	.022	.212
161.0	1.293	.050	.196
166.3	1.296	.073	.171
166.3	1.314	.087	.145
169.9	1.297	.100	.138
173.6	1.268	.146	.089
177.3	1.228	.147	.087
180.7	1.243	.094	.185
181.0	1.234	.069	.205
188.4	1.306	.059	.320
193.8	1.304	.086	.278
195.2	1.319	.097	.284
198.6	1.312	.099	.248
199.4	1.301	.099	.249
209.5	1.314	.122	.212
211.2	1.313	.122	.201
224.0	1.304	.137	.170
224.1	1.307	.136	.168
236.7	1.292	.146	.138
238.3	1.286	.146	.138
249.9	1.272	.149	.114
252.7	1.268	.148	.111
262.8	1.235	.150	.085
267.2	1.239	.147	.079
281.5	1.186	.140	.049
295.8	1.112	.128	.026
295.9	1.101	.128	.011
308.5	1.012	.107	-.026
312.0	1.018	.089	-.017
321.1	.924	.005	-.026
328.4	.962	-.009	.039
333.9	.896	-.031	.050
345.0	.869	-.036	.085
347.0	.866	-.046	.097
352.5	.858	-.045	.097
353.6	.871	-.035	.095
356.0	.878	-.035	.084
359.8	.889	-.035	.066

RADIUS = .868

ANGLE	VX/V	VT/V	VR/V
.2	.737	-.048	-.011
1.9	.755	-.090	-.036
3.7	.783	-.128	-.055
5.5	.830	-.170	-.078
7.3	.889	-.201	-.094
10.9	.981	-.219	-.108
14.5	1.010	-.210	-.091
15.9	1.053	-.203	-.089
18.2	1.046	-.197	-.078
21.8	1.076	-.187	-.053

TABLE 1 - CONTINUED

ANGLE	RADIUS = .868 VX/V	VT/V	VR/V
25.4	1.110	-.186	-.035
30.7	1.149	-.177	-.010
33.8	1.159	-.171	.002
37.8	1.162	-.160	.025
39.6	1.159	-.159	.037
43.3	1.148	-.151	.062
51.9	1.151	-.134	.091
61.2	1.179	-.122	.114
69.8	1.229	-.118	.137
79.3	1.278	-.106	.158
87.9	1.302	-.090	.168
97.4	1.315	-.064	.175
106.0	1.326	-.045	.184
117.3	1.339	-.011	.189
124.0	1.338	.005	.193
136.0	1.348	.023	.190
142.1	1.327	.041	.199
145.3	1.345	.047	.186
146.1	1.333	.054	.184
153.3	1.328	.073	.178
167.5	1.308	.155	.159
168.0	1.327	.154	.173
171.5	1.329	.198	.172
175.4	1.331	.278	.152
179.1	1.227	.286	.045
179.8	1.209	.225	.060
181.5	1.266	.216	.124
182.9	1.267	.214	.146
183.4	1.318	.237	.235
187.1	1.349	.231	.254
189.6	1.326	.213	.234
190.3	1.328	.218	.250
190.6	1.348	.198	.231
194.2	1.351	.181	.209
197.8	1.349	.175	.195
206.8	1.339	.167	.157
206.8	1.334	.169	.171
215.8	1.332	.169	.138
224.9	1.322	.172	.121
233.8	1.314	.177	.105
233.8	1.314	.178	.104
242.8	1.299	.181	.087
251.8	1.277	.187	.069
260.9	1.266	.186	.056
279.0	1.194	.183	.025
297.1	1.069	.174	-.012
300.7	1.044	.172	-.023
308.0	.998	.182	-.050
311.6	.936	.167	-.057
315.1	.932	.175	-.081
318.6	.884	.160	-.085
321.9	.815	.120	-.081
322.1	.843	.126	-.082
324.0	.828	.108	-.074
327.6	.805	.060	-.043
331.2	.785	.037	-.011
334.9	.794	.035	.022
338.5	.788	.031	.050
339.9	.774	.032	.044
340.2	.796	.038	.057
342.1	.796	.044	.062
343.9	.778	.036	.073
345.7	.755	.038	.095
347.6	.739	.030	.107
349.2	.725	.035	.121
351.1	.712	.056	.122
354.8	.703	.040	.069
356.5	.701	.024	.039
357.9	.760	-.004	-.006
358.3	.716	-.009	.011

TABLE 2 - LISTING OF THE MEAN VELOCITY COMPONENT RATIOS, THE MEAN ADVANCE ANGLES AND OTHER DERIVED QUANTITIES AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE ARS-50 WITH PROPELLER AND NOZZLE

ARS WAKE SURVEY WITH PROPELLER AND NOZZLE
PROPELLER DIAMETER = 10.50 FEET JV = .932

RADIUS =	.451	.591	.735	.868	.299	.300	.400	.500	.600	.700	.800	.900	1.000
VXBAR =	1.238	1.220	1.186	1.177	1.240	1.240	1.241	1.234	1.217	1.192	1.179	1.177	1.177
VTBAR =	-.035	.039	-.006	.050	-.247	-.245	-.090	.005	.033	-.005	.010	.050	.050
VRBAR =	.203	.109	.126	.089	.428	.426	.264	.157	.111	.127	.114	.089	.089
1-WVX =	1.239	1.235	1.221	1.208	0.000	1.240	1.241	1.239	1.234	1.224	1.213	1.205	1.199
1-WX =	1.488	1.326	1.269	1.239	0.000	1.798	1.490	1.370	1.306	1.271	1.248	1.229	1.214
BBAR =	39.80	30.99	25.63	21.58	58.44	58.27	44.60	36.13	30.63	26.85	23.53	20.89	18.98
BPOS =	5.47	3.32	3.17	3.14	14.18	14.10	6.92	4.55	3.20	3.09	3.21	3.04	2.77
THETA =	57.50	52.50	97.50	107.50	20.00	20.00	20.00	52.50	52.50	95.00	100.00	110.00	110.00
BNEG =	-6.61	-5.19	-6.21	-8.29	-19.99	-19.79	-8.53	-5.89	-5.11	-5.69	-7.21	-8.05	-7.37
THETA =	325.00	317.50	0.00	352.50	177.50	177.50	325.00	315.00	317.50	342.50	352.50	352.50	352.50

VXBAR IS CIRCUMFERENTIAL MEAN LONGITUDINAL VELOCITY.
VTBAR IS CIRCUMFERENTIAL MEAN TANGENTIAL VELOCITY.
VRBAR IS CIRCUMFERENTIAL MEAN RADIAL VELOCITY.
1-WVX IS VOLUMETRIC MEAN WAKE VELOCITY WITHOUT TANGENTIAL CORRECTION.
1-WX IS VOLUMETRIC MEAN WAKE VELOCITY WITH TANGENTIAL CORRECTION.
BBAR IS MEAN ANGLE OF ADVANCE.
BPOS IS VARIATION BETWEEN THE MAXIMUM AND MEAN ADVANCE ANGLES (DELTA BETA PLUS).
BNEG IS VARIATION BETWEEN THE MINIMUM AND MEAN ADVANCE ANGLES (DELTA BETA MINUS).
THETA IS ANGLE IN DEGREES AT WHICH CORRESPONDING BPOS OR BNEG OCCURS.

TABLE 3 - HARMONIC ANALYSIS OF THE LONGITUDINAL VELOCITY COMPONENT RATIOS AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE ARS-50 WITH PROPELLER AND NOZZLE

ARS WAKE SURVEY WITH PROPELLER AND NOZZLE
PROPELLER DIAMETER = 10.50 FEET JV = .932

HARMONIC ANALYSES OF LONGITUDINAL VELOCITY COMPONENT RATIOS (VX/V)

HARMONIC =	1	2	3	4	5	6	7	8
RADIUS = .451								
AMPLITUDE =	.0913	.0680	.0318	.0188	.0142	.0099	.0119	.0122
PHASE ANGLE =	293.6	320.3	10.2	5.3	107.8	215.4	196.4	250.5
RADIUS = .591								
AMPLITUDE =	.1271	.0678	.0347	.0183	.0008	.0023	.0078	.0052
PHASE ANGLE =	287.4	319.9	346.6	3.7	37.1	190.6	212.9	237.6
RADIUS = .735								
AMPLITUDE =	.1737	.0837	.0345	.0311	.0150	.0232	.0099	.0079
PHASE ANGLE =	285.6	307.5	349.1	331.5	311.3	271.2	249.6	260.7
RADIUS = .868								
AMPLITUDE =	.2356	.1134	.0456	.0387	.0182	.0222	.0112	.0112
PHASE ANGLE =	285.7	304.1	337.6	340.4	328.2	300.1	265.2	261.6
RADIUS = .299								
AMPLITUDE =	.0667	.0856	.0454	.0328	.0301	.0459	.0201	.0312
PHASE ANGLE =	310.3	307.8	55.3	334.0	99.9	247.0	200.3	260.4
RADIUS = .300								
AMPLITUDE =	.0668	.0854	.0452	.0326	.0300	.0455	.0200	.0310
PHASE ANGLE =	310.1	307.9	55.1	334.2	99.9	246.9	200.2	260.4
RADIUS = .400								
AMPLITUDE =	.0811	.0716	.0330	.0212	.0194	.0181	.0143	.0172
PHASE ANGLE =	297.8	317.1	25.7	355.3	105.4	232.7	196.5	254.9
RADIUS = .500								
AMPLITUDE =	.1027	.0664	.0324	.0173	.0093	.0058	.0100	.0087
PHASE ANGLE =	290.7	321.8	358.5	10.4	109.3	188.1	198.7	245.1
RADIUS = .600								
AMPLITUDE =	.1294	.0682	.0344	.0188	.0015	.0036	.0078	.0053
PHASE ANGLE =	287.2	318.9	347.3	358.9	331.8	228.5	216.2	240.2
RADIUS = .700								
AMPLITUDE =	.1604	.0781	.0335	.0281	.0125	.0203	.0093	.0071
PHASE ANGLE =	285.8	309.6	350.3	333.2	309.3	267.1	243.5	258.1
RADIUS = .800								
AMPLITUDE =	.2017	.0966	.0384	.0355	.0177	.0247	.0108	.0094
PHASE ANGLE =	285.5	305.1	344.3	333.4	317.4	281.0	258.3	262.5
RADIUS = .900								
AMPLITUDE =	.2356	.1134	.0456	.0387	.0182	.0222	.0112	.0112
PHASE ANGLE =	285.7	304.1	337.6	340.4	328.2	300.1	265.2	261.6
RADIUS = 1.000								
AMPLITUDE =	.2356	.1134	.0456	.0387	.0182	.0222	.0112	.0112
PHASE ANGLE =	285.7	304.1	337.6	340.4	328.2	300.1	265.2	261.6

TABLE 4 - HARMONIC ANALYSIS OF THE TANGENTIAL VELOCITY COMPONENT RATIOS AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE ARS-50 WITH PROPELLER AND NOZZLE

ARS WAKE SURVEY WITH PROPELLER AND NOZZLE
PROPELLER DIAMETER = 10.50 FEET JV - .932

HARMONIC ANALYSES OF TANGENTIAL VELOCITY COMPONENT RATIOS (VT/V)

HARMONIC =	1	2	3	4	5	6	7	8
RADIUS = .451								
AMPLITUDE =	.2058	.0366	.0038	.0056	.0069	.0028	.0061	.0063
PHASE ANGLE =	212.4	225.3	91.2	294.8	25.1	110.8	81.8	136.0
RADIUS = .591								
AMPLITUDE =	.1756	.0369	.0201	.0124	.0204	.0036	.0140	.0047
PHASE ANGLE =	213.6	238.0	63.8	351.4	64.6	83.7	94.8	189.5
RADIUS = .735								
AMPLITUDE =	.1781	.0319	.0011	.0136	.0132	.0155	.0088	.0091
PHASE ANGLE =	210.8	180.5	119.9	101.4	55.7	107.8	69.3	131.5
RADIUS = .868								
AMPLITUDE =	.1825	.0423	.0358	.0144	.0155	.0204	.0076	.0183
PHASE ANGLE =	216.1	181.3	236.3	146.5	230.3	118.3	178.0	131.8
RADIUS = .299								
AMPLITUDE =	.2754	.0561	.0548	.0359	.0394	.0157	.0201	.0247
PHASE ANGLE =	208.9	160.1	236.9	173.1	269.2	127.5	299.9	103.8
RADIUS = .300								
AMPLITUDE =	.2748	.0558	.0543	.0356	.0390	.0156	.0199	.0245
PHASE ANGLE =	208.9	160.5	236.9	173.2	269.3	127.5	300.0	103.8
RADIUS = .400								
AMPLITUDE =	.2248	.0360	.0118	.0080	.0094	.0055	.0031	.0105
PHASE ANGLE =	211.4	205.5	228.9	205.3	298.2	123.3	358.0	117.3
RADIUS = .500								
AMPLITUDE =	.1916	.0384	.0133	.0100	.0133	.0018	.0103	.0046
PHASE ANGLE =	213.2	235.9	67.5	328.5	55.3	83.3	93.0	165.2
RADIUS = .600								
AMPLITUDE =	.1757	.0349	.0194	.0112	.0207	.0045	.0136	.0046
PHASE ANGLE =	213.2	234.3	63.7	358.7	63.6	89.0	91.8	183.6
RADIUS = .700								
AMPLITUDE =	.1773	.0294	.0072	.0116	.0172	.0132	.0105	.0072
PHASE ANGLE =	210.7	189.4	66.8	87.6	56.7	105.2	70.1	136.1
RADIUS = .800								
AMPLITUDE =	.1798	.0372	.0151	.0152	.0019	.0186	.0047	.0133
PHASE ANGLE =	212.5	175.5	234.7	120.9	61.5	112.6	94.4	129.8
RADIUS = .900								
AMPLITUDE =	.1825	.0423	.0358	.0144	.0155	.0204	.0076	.0183
PHASE ANGLE =	216.1	181.3	236.3	146.5	230.3	118.3	178.0	131.8
RADIUS = 1.000								
AMPLITUDE =	.1825	.0423	.0358	.0144	.0155	.0204	.0076	.0183
PHASE ANGLE =	216.1	181.3	236.3	146.5	230.3	118.3	178.0	131.8

TABLE 5 - EXPERIMENTAL WAKE SURVEY DATA FOR THE ARS-50 WITHOUT PROPELLER, WITH NOZZLE

RADIUS = .451

ANGLE	VX/V	VT/V	VR/V
.3	.923	-.084	.122
.3	.948	-.084	.123
2.6	.911	-.083	.122
4.5	.910	-.089	.119
6.3	.915	-.097	.118
8.1	.918	-.110	.109
9.9	.930	-.124	.111
11.5	1.019	-.147	.126
11.7	.957	-.139	.108
13.2	.981	-.153	.108
13.6	.984	-.151	.112
15.4	1.022	-.158	.114
17.1	1.048	-.168	.114
19.8	1.070	-.177	.112
22.5	1.082	-.181	.106
26.1	1.088	-.190	.102
29.7	1.091	-.193	.105
36.8	1.090	-.198	.118
44.1	1.091	-.197	.134
54.7	1.090	-.206	.156
62.0	1.099	-.192	.171
72.7	1.100	-.187	.192
80.0	1.100	-.166	.201
90.8	1.098	-.150	.213
99.5	1.097	-.124	.221
108.8	1.096	-.105	.223
116.0	1.089	-.075	.227
126.6	1.086	-.056	.224
133.9	1.072	-.035	.224
144.7	1.077	.004	.220
152.0	1.066	.028	.228
164.6	1.085	.063	.227
166.5	1.092	.077	.227
168.2	1.098	.088	.224
170.0	1.111	.100	.220
173.7	1.126	.120	.205
175.4	1.125	.131	.200
177.3	1.072	.050	.230
179.1	1.041	.029	.223
180.3	1.063	.013	.241
183.0	1.039	.028	.232
184.2	1.069	.050	.238
184.5	1.052	.031	.237
186.5	1.078	.031	.248
187.9	1.064	.151	.145
190.1	1.063	.146	.158
192.0	1.066	.133	.178
193.9	1.073	.121	.197
196.0	1.088	.113	.223
196.7	1.115	.084	.293
198.0	1.112	.076	.245
199.9	1.111	.068	.244
201.3	1.103	.068	.242
205.9	1.124	.102	.257
214.8	1.103	.124	.245
225.6	1.109	.127	207
232.7	1.107	.139	.201
241.9	1.111	.145	.183
250.7	1.100	.145	.168
259.9	1.111	.143	.153
268.7	1.098	.140	.136

RADIUS = .451

ANGLE	VX/V	VT/V	VR/V
277.9	1.098	.128	.119
281.4	1.090	.129	.109
286.7	1.079	.121	.103
297.6	1.042	.097	.089
304.7	.935	.086	.093
313.9	.896	.058	.094
322.7	.869	-.011	.110
328.5	.888	-.049	.107
330.2	.883	-.044	.105
340.9	.918	-.079	.103
345.3	.943	-.076	.106
347.3	.952	-.083	.107
349.2	.949	-.083	.109
350.6	.950	-.084	.110
353.1	.968	-.084	.113
356.9	.950	-.082	.119
357.1	.932	-.087	.119
360.3	.923	-.084	.122

RADIUS = .591

ANGLE	VX/V	VT/V	VR/V
1.2	.822	-.011	.024
3.1	.842	-.013	.028
4.8	.843	-.013	.021
6.8	.855	-.015	.023
8.5	.853	-.022	.018
10.5	.865	-.023	.016
12.2	.874	-.035	.013
14.1	.895	-.047	.006
16.2	.954	-.068	-.009
19.4	.944	-.081	-.025
27.3	1.031	-.109	-.006
28.5	1.044	-.106	-.006
34.1	1.051	-.120	.019
46.4	1.074	-.128	.049
52.1	1.076	-.127	.069
64.5	1.085	-.120	.097
70.1	1.085	-.112	.116
82.6	1.091	-.090	.132
88.1	1.088	-.073	.145
100.5	1.090	-.053	.149
106.1	1.087	-.034	.155
118.7	1.091	-.012	.153
124.1	1.092	.006	.158
136.7	1.091	.025	.152
142.2	1.090	.041	.149
147.6	1.094	.068	.159
151.3	1.096	.078	.157
154.7	1.094	.060	.137
154.8	1.098	.090	.158
156.5	1.097	.063	.135
158.2	1.095	.065	.132
158.4	1.098	.095	.156
160.2	1.098	.070	.128
163.8	1.107	.076	.122
165.7	1.117	.078	.120
167.6	1.131	.088	.114
169.2	1.136	.090	.105
169.2	1.135	.084	.108
171.0	1.126	.089	.093
172.8	1.106	.073	.064

TABLE 5 - CONTINUED

RADIUS = .591

ANGLE	VX/V	VT/V	VR/V
174.7	1.101	.037	.083
176.4	1.124	.011	.106
178.1	1.141	-.016	.158
178.2	1.136	.002	.142
180.0	1.150	.006	.165
182.0	1.162	.017	.209
183.7	1.156	.030	.214
185.6	1.140	.042	.212
187.4	1.139	.060	.214
189.0	1.136	.069	.211
192.5	1.117	.093	.209
196.2	1.110	.111	.200
196.2	1.112	.110	.200
199.8	1.112	.125	.191
203.4	1.108	.136	.179
214.2	1.097	.162	.146
221.4	1.099	.174	.128
232.2	1.093	.185	.106
239.4	1.093	.189	.091
250.1	1.088	.193	.070
257.4	1.083	.193	.055
268.2	1.064	.191	.030
275.5	1.061	.187	.017
286.2	1.015	.173	-.006
293.4	.985	.159	-.016
304.2	.906	.132	-.022
311.4	.834	.085	-.023
315.1	.797	.052	-.023
318.7	.789	.034	-.019
322.3	.788	.006	-.017
322.3	.800	.009	-.019
326.0	.792	-.007	-.012
329.7	.792	-.011	-.006
333.5	.792	-.019	-.006
340.9	.806	-.023	.018
342.8	.805	-.021	.022
344.7	.788	-.027	.022
346.6	.791	-.022	.024
348.7	.803	-.022	.027
350.5	.809	-.018	.030
352.4	.806	-.021	.037
356.4	.824	-.018	.031
359.7	.831	-.012	.033

RADIUS = .735

ANGLE	VX/V	VT/V	VR/V
.3	.681	-.013	.042
2.6	.691	-.020	.029
4.3	.736	-.031	.030
4.5	.707	-.029	.023
6.3	.724	-.032	.007
8.1	.734	-.046	-.002
9.9	.765	-.066	-.012
11.5	.874	-.085	-.008
11.7	.795	-.081	-.023
13.2	.819	-.097	-.036
13.6	.825	-.108	-.028
15.4	.878	-.124	-.033
17.1	.915	-.136	-.040
18.8	.971	-.149	-.041
22.5	.982	-.161	-.034

RADIUS = .735

ANGLE	VX/V	VT/V	VR/V
26.1	1.004	-.173	-.014
29.7	1.022	-.182	.001
36.8	1.037	-.186	.025
44.1	1.042	-.184	.054
54.7	1.016	-.181	.079
62.0	1.035	-.171	.110
72.7	1.050	-.163	.136
80.0	1.069	-.146	.158
90.8	1.087	-.125	.163
99.5	1.099	-.101	.177
108.8	1.096	-.085	.174
116.0	1.098	-.065	.185
126.6	1.094	-.044	.177
133.9	1.088	-.029	.181
144.7	1.087	-.004	.185
152.0	1.078	.003	.186
164.6	1.091	.018	.171
166.5	1.100	.015	.166
168.2	1.105	.013	.157
170.0	1.106	.005	.139
173.7	1.087	-.060	.115
175.4	1.094	-.099	.128
177.3	1.048	.191	.049
179.1	1.002	.182	.091
180.3	1.014	.182	.025
183.0	1.005	.115	.212
184.2	1.089	.067	.262
184.5	1.056	.068	.274
186.5	1.105	.060	.290
187.9	1.135	.017	.185
190.1	1.135	.036	.179
192.0	1.131	.049	.175
193.9	1.128	.057	.172
196.0	1.132	.065	.172
196.7	1.120	.096	.174
198.0	1.115	.076	.186
199.9	1.114	.082	.200
201.3	1.113	.084	.195
205.9	1.126	.089	.162
214.8	1.108	.117	.141
225.6	1.110	.112	.128
232.7	1.104	.121	.111
241.9	1.102	.124	.099
250.7	1.086	.127	.080
259.9	1.092	.130	.066
268.7	1.056	.134	.042
277.9	1.041	.128	.031
281.4	1.014	.127	.020
286.7	.988	.123	.011
297.6	.933	.106	-.010
304.7	.871	.091	-.025
313.9	.790	.054	-.040
322.7	.741	-.006	-.035
330.2	.733	-.018	-.000
340.9	.703	-.036	.052
345.3	.697	-.038	.055
347.1	.685	-.033	.058
347.3	.696	-.032	.068
349.2	.683	-.032	.068
349.9	.673	-.026	.066
350.6	.689	-.028	.069

TABLE 5 - CONTINUED

RADIUS = .735

ANGLE	VX/V	VT/V	VR/V
353.1	.671	-.026	.068
356.9	.674	-.015	.064
357.1	.688	-.016	.053
360.3	.681	-.013	.042

RADIUS = .868

ANGLE	VX/V	VT/V	VR/V
-.2	.525	.018	.006
1.2	.535	-.012	-.007
3.1	.556	-.039	-.017
4.8	.566	-.066	-.033
6.8	.586	-.091	-.048
8.5	.626	-.137	-.062
10.5	.686	-.157	-.074
12.2	.745	-.168	-.087
14.1	.801	-.176	-.097
16.2	.869	-.159	-.091
19.4	.854	-.167	-.091
27.3	.944	-.153	-.027
28.5	.959	-.151	-.040
34.1	1.003	-.144	-.002
46.4	1.022	-.122	.030
52.1	.994	-.103	.057
64.5	1.035	-.102	.077
70.1	1.054	-.091	.101
82.6	1.098	-.090	.119
88.1	1.127	-.072	.136
100.5	1.136	-.055	.135
106.1	1.137	-.037	.146
118.7	1.148	-.021	.141
124.1	1.150	-.006	.144
136.7	1.152	.012	.146
142.2	1.150	.028	.139
147.6	1.158	.038	.147
151.3	1.159	.045	.150
154.7	1.158	.050	.145
154.8	1.160	.054	.152
156.5	1.160	.056	.142
158.2	1.158	.062	.140
158.4	1.157	.059	.152
162.0	1.149	.068	.151
163.8	1.147	.095	.147
165.7	1.145	.104	.152
167.6	1.147	.119	.157
169.2	1.144	.130	.163
169.2	1.142	.129	.166
171.0	1.147	.149	.162
172.8	1.148	.175	.157
174.7	1.134	.195	.130
176.4	1.066	.172	.057
178.1	1.027	.114	.028
178.2	1.023	.109	.024
180.0	1.082	.085	.102
182.0	1.139	.123	.155
183.7	1.168	.155	.174
185.6	1.169	.166	.178
187.4	1.168	.168	.186
189.0	1.177	.157	.174
192.5	1.160	.148	.160
196.2	1.153	.143	.150
196.2	1.153	.143	.150

RADIUS = .868

ANGLE	VX/V	VT/V	VR/V
199.8	1.155	.140	.141
203.4	1.155	.139	.128
214.2	1.140	.145	.104
221.4	1.142	.149	.090
232.2	1.126	.155	.074
239.4	1.124	.157	.064
250.1	1.107	.163	.051
257.4	1.099	.165	.037
268.2	1.056	.173	.016
275.5	1.037	.170	.011
286.2	.945	.162	-.012
293.4	.906	.157	-.024
304.2	.832	.151	-.041
311.4	.791	.146	-.069
315.1	.748	.146	-.080
318.7	.695	.115	-.087
322.3	.666	.096	-.078
322.3	.662	.087	-.075
326.0	.645	.064	-.057
329.7	.631	.047	-.042
333.5	.633	.036	-.019
337.2	.612	.045	.009
340.9	.620	.037	.021
341.0	.622	.041	.026
342.8	.612	.033	.027
344.7	.596	.047	.044
346.6	.588	.042	.060
348.7	.573	.038	.081
350.5	.560	.038	.083
352.4	.544	.040	.080
356.4	.534	.055	.054
358.1	.523	.032	.018
359.7	.532	.024	.010
359.8	.525	.018	.006

TABLE 6 - LISTING OF THE MEAN VELOCITY COMPONENT RATIOS, THE MEAN ADVANCE ANGLES AND OTHER DERIVED QUANTITIES AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE ARS-50 WITHOUT PROPELLER, WITH NOZZLE

ARS WAKE SURVEY WITH NOZZLE, WITHOUT PROPELLER
PROPELLER DIAMETER = 10.50 FEET JV = .932

RADIUS =	.451	.591	.735	.868	.299	.300	.400	.500	.600	.700	.800	.900	1.000
VXBAR =	1.057	1.027	1.001	.996	1.095	1.095	1.069	1.046	1.024	1.005	.996	.996	.996
VTBAR =	-.013	.037	-.007	.042	-.171	-.169	-.054	.015	.031	-.005	.006	.042	.042
VRBAR =	.169	.081	.092	.061	.374	.373	.225	.127	.083	.094	.082	.061	.061
1-WVX =	1.072	1.055	1.037	1.024	0.000	1.095	1.081	1.068	1.054	1.041	1.030	1.022	1.016
1-WX =	1.201	1.099	1.059	1.038	0.000	1.392	1.219	1.137	1.090	1.063	1.047	1.033	1.022
BBAR =	35.03	26.83	22.05	18.54	52.61	52.45	39.55	31.59	26.51	23.12	20.23	17.94	16.26
BPOS =	4.63	3.26	2.78	3.11	16.50	16.41	7.32	4.05	3.18	2.87	2.93	3.00	2.70
THETA =	55.00	62.50	97.50	95.00	20.00	20.00	20.00	57.50	62.50	175.00	95.00	95.00	95.00
BNEG =	-5.56	-5.61	-6.72	-8.50	-23.94	-23.68	-5.71	-5.61	-5.54	-6.21	-7.57	-8.24	-7.51
THETA =	317.50	317.50	355.00	357.50	180.00	180.00	190.00	317.50	317.50	355.00	355.00	357.50	0.00

VXBAR IS CIRCUMFERENTIAL MEAN LONGITUDINAL VELOCITY.
VTBAR IS CIRCUMFERENTIAL MEAN TANGENTIAL VELOCITY.
VRBAR IS CIRCUMFERENTIAL MEAN RADIAL VELOCITY.
1-WVX IS VOLUMETRIC MEAN WAKE VELOCITY WITHOUT TANGENTIAL CORRECTION.
1-WX IS VOLUMETRIC MEAN WAKE VELOCITY WITH TANGENTIAL CORRECTION.
BBAR IS MEAN ANGLE OF ADVANCE.
BPOS IS VARIATION BETWEEN THE MAXIMUM AND MEAN ADVANCE ANGLES (DELTA BETA PLUS).
BNEG IS VARIATION BETWEEN THE MINIMUM AND MEAN ADVANCE ANGLES (DELTA BETA MINUS).
THETA IS ANGLE IN DEGREES AT WHICH CORRESPONDING BPOS OR BNEG OCCURS.

TABLE 7 - HARMONIC ANALYSIS OF THE LONGITUDINAL VELOCITY COMPONENT RATIOS AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE ARS-50 WITHOUT PROPELLER, WITH NOZZLE

ARS WAKE SURVEY WITH NOZZLE, WITHOUT PROPELLER
PROPELLER DIAMETER = 10.50 FEET　　　　UV = .932

HARMONIC ANALYSES OF LONGITUDINAL VELOCITY COMPONENT RATIOS (VX/V)

HARMONIC =	1	2	3	4	5	6	7	8
RADIUS = .451								
AMPLITUDE =	.0647	.0633	.0287	.0158	.0049	.0118	.0089	.0158
PHASE ANGLE =	290.0	318.7	346.1	16.3	92.8	195.6	221.3	222.5
RADIUS = .591								
AMPLITUDE =	.1289	.0760	.0413	.0129	.0063	.0074	.0121	.0050
PHASE ANGLE =	290.3	320.2	327.7	17.3	232.4	189.9	231.7	228.9
RADIUS = .735								
AMPLITUDE =	.1576	.0998	.0425	.0301	.0137	.0187	.0112	.0133
PHASE ANGLE =	286.0	311.5	334.6	335.1	289.1	266.9	239.2	249.7
RADIUS = .868								
AMPLITUDE =	.2355	.1166	.0504	.0330	.0220	.0245	.0129	.0117
PHASE ANGLE =	286.3	304.5	326.5	319.1	290.8	274.3	228.0	242.8
RADIUS = .299								
AMPLITUDE =	.0480	.0636	.0348	.0398	.0246	.0296	.0036	.0476
PHASE ANGLE =	127.4	300.2	62.1	342.2	47.2	242.7	147.7	228.2
RADIUS = .300								
AMPLITUDE =	.0471	.0635	.0346	.0395	.0244	.0294	.0036	.0473
PHASE ANGLE =	127.5	300.3	61.8	342.4	47.3	242.5	148.8	228.2
RADIUS = .400								
AMPLITUDE =	.0325	.0612	.0247	.0205	.0099	.0150	.0069	.0241
PHASE ANGLE =	284.4	314.3	7.7	2.4	66.5	214.5	212.7	224.8
RADIUS = .500								
AMPLITUDE =	.0913	.0657	.0339	.0136	.0031	.0102	.0105	.0101
PHASE ANGLE =	291.0	320.8	335 C	26.0	156.7	182.2	226.1	220.5
RADIUS = .600								
AMPLITUDE =	.1289	.0777	.0411	.0140	.0063	.0073	.0120	.0057
PHASE ANGLE =	289.9	319.6	328.6	10.7	239.9	201.7	232.7	234.0
RADIUS - .700								
AMPLITUDE =	.1452	.0946	.0415	.0270	.0114	.0157	.0112	.0122
PHASE ANGLE =	286.5	313.4	334.6	339.9	284.8	261.9	239.3	249.2
RADIUS = .800								
AMPLITUDE =	.1895	.1086	.0454	.0333	.0179	.0228	.0117	.0136
PHASE ANGLE =	285.8	308.0	332.0	327.7	291.7	271.8	235.5	246.4
RADIUS = .900								
AMPLITUDE =	.2355	.1166	.0504	.0330	.0220	.0245	.0129	.0117
PHASE ANGLE =	286.3	304.5	326.5	319.1	290.8	274.3	228.0	242.8
RADIUS = 1.000								
AMPLITUDE =	.2355	.1166	.0504	.0330	.0220	.0245	.0129	.0117
PHASE ANGLE =	286.3	304.5	326.5	319.1	290.8	274.3	228.0	242.8

TABLE 8 - HARMONIC ANALYSIS OF THE TANGENTIAL VELOCITY COMPONENT RATIOS AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE ARS-50 WITHOUT PROPELLER, WITH NOZZLE

ARS WAKE SURVEY WITH NOZZLE, WITHOUT PROPELLER
PROPELLER DIAMETER = 10.50 FEET UV = .932

HARMONIC ANALYSES OF TANGENTIAL VELOCITY COMPONENT RATIOS (VT/V)

HARMONIC =	1	2	3	4	5	6	7	8
RADIUS = .451								
AMPLITUDE =	.1709	.0220	.0075	.0051	.0087	.0076	.0066	.0044
PHASE ANGLE =	214.3	197.1	346.8	79.4	36.4	98.8	78.1	127.6
RADIUS = .591								
AMPLITUDE =	.1455	.0246	.0211	.0074	.0211	.0022	.0116	.0039
PHASE ANGLE =	210.4	243.3	50.0	10.4	66.0	152.1	85.3	243.5
RADIUS = .735								
AMPLITUDE =	.1473	.0225	.0090	.0121	.0128	.0116	.0065	.0083
PHASE ANGLE =	207.7	193.9	94.0	62.7	87.0	86.2	100.6	83.2
RADIUS = .868								
AMPLITUDE =	.1507	.0322	.0220	.0127	.0092	.0163	.0083	.0131
PHASE ANGLE =	210.6	190.0	224.1	142.3	176.3	122.2	126.4	128.4
RADIUS = .299								
AMPLITUDE =	.2295	.0713	.0534	.0276	.0335	.0335	.0104	.0317
PHASE ANGLE =	217.8	140.1	245.8	122.6	261.0	84.2	269.6	93.3
RADIUS = .300								
AMPLITUDE =	.2290	.0707	.0529	.0273	.0332	.0333	.0102	.0315
PHASE ANGLE =	217.8	140.2	245.9	122.5	261.1	84.3	269.7	93.4
RADIUS = .400								
AMPLITUDE =	.1870	.0305	.0143	.0100	.0065	.0140	.0024	.0109
PHASE ANGLE =	215.6	166.9	270.3	109.4	309.0	90.3	62.6	104.0
RADIUS = .500								
AMPLITUDE =	.1589	.0217	.0138	.0046	.0151	.0038	.0095	.0028
PHASE ANGLE =	212.9	225.4	32.0	29.2	55.3	118.2	81.5	201.7
RADIUS = .600								
AMPLITUDE =	.1455	.0236	.0207	.0080	.0208	.0023	.0111	.0028
PHASE ANGLE =	210.1	240.1	52.0	16.9	66.8	125.1	85.5	244.3
RADIUS = .700								
AMPLITUDE =	.1467	.0207	.0129	.0122	.0153	.0099	.0072	.0065
PHASE ANGLE =	207.8	202.1	76.4	52.5	79.3	82.1	94.0	76.4
RADIUS = .800								
AMPLITUDE =	.1408	.0269	.0078	.0107	.0085	.0138	.0066	.0105
PHASE ANGLE =	208.5	187.7	185.5	92.0	116.9	100.1	115.4	101.5
RADIUS = .900								
AMPLITUDE =	.1507	.0322	.0220	.0127	.0092	.0163	.0083	.0131
PHASE ANGLE =	210.6	190.0	224.1	142.3	176.3	122.2	126.4	128.4
RADIUS = 1.000								
AMPLITUDE =	.1507	.0322	.0220	.0127	.0092	.0163	.0083	.0131
PHASE ANGLE =	210.6	190.0	224.1	142.3	176.3	122.2	126.4	128.4

TABLE 9 - EXPERIMENTAL WAKE SURVEY DATA FOR THE ARS-50 WITHOUT NOZZLE OR PROPELLER

RADIUS = .451

ANGLE	VX/V	VT/V	VR/V
-.8	.887	-.091	.090
7.4	.909	-.130	.099
16.4	1.018	-.187	.097
25.4	1.059	-.209	.084
34.4	1.051	-.219	.094
43.4	1.055	-.229	.114
52.4	1.054	-.236	.136
61.3	1.055	-.233	.158
70.4	1.051	-.222	.177
79.5	1.048	-.205	.194
88.4	1.047	-.183	.208
98.1	1.047	-.160	.218
106.4	1.031	-.130	.225
115.5	1.035	-.093	.229
133.5	1.031	-.030	.229
151.5	1.039	.025	.227
160.5	1.021	.063	.220
169.5	1.042	.101	.215
178.4	1.013	.156	.172
187.5	.979	.171	.133
196.5	1.004	.139	.216
205.6	1.055	.148	.274
214.5	1.058	.165	.255
223.5	1.053	.177	.218
232.6	1.058	.188	.196
241.4	1.051	.190	.173
251.0	1.057	.191	.156
259.5	1.059	.183	.135
270.2	1.057	.180	.118
277.5	1.061	.163	.098
266.6	1.053	.147	.084
295.6	1.041	.125	.072
304.6	.986	.105	.071
313.7	.844	.078	.073
322.8	.782	.011	.076
331.8	.845	-.045	.074
340.9	.269	-.073	.076
350.1	.894	-.085	.082
356.0	.883	-.089	.067
359.2	.887	-.091	.090

RADIUS = .591

ANGLE	VX/V	VT/V	VR/V
-1.6	.837	-.016	-.004
5.7	.862	-.022	-.008
16.4	.933	-.089	-.049
23.7	1.019	-.112	-.044
34.4	1.021	-.137	-.017
41.5	1.030	-.150	.004
52.4	1.027	-.159	.042
59.5	1.041	-.155	.068
70.4	1.031	-.142	.105
77.6	1.023	-.127	.121
88.3	1.029	-.097	.145
95.7	1.020	-.079	.150
106.3	1.016	-.045	.163
113.7	1.012	-.026	.165
124.4	1.002	.009	.169
131.9	1.005	.028	.169
142.5	1.006	.060	.169
149.9	1.013	.085	.166
150.6	1.012	.080	.167
155.3	1.011	.101	.164
160.7	1.005	.120	.161
168.0	1.002	.157	.155
169.5	1.007	.169	.156
178.7	.960	.195	.110
179.7	.982	.204	.116
185.8	.938	.151	.116
196.7	1.020	.192	.164
203.8	1.025	.221	.164
214.6	1.024	.231	.142
221.7	1.027	.239	.124
232.6	1.028	.243	.090
239.7	1.024	.247	.071
250.5	1.020	.247	.043
257.8	1.023	.243	.023
268.5	1.004	.236	-.007
275.8	1.006	.226	-.024
293.7	.942	.191	-.063
304.5	.870	.157	-.063
311.7	.866	.114	-.058
322.5	.766	.024	-.040
329.6	.785	-.001	-.037
340.5	.799	-.016	-.026
347.6	.809	-.015	-.007
356.0	.831	-.016	-.005
358.4	.837	-.016	-.004

TABLE 9 - CONTINUED

RADIUS = .735

ANGLE	VX/V	VT/V	VR/V
-1.6	.710	-.036	.019
7.4	.730	-.038	-.023
16.4	.855	-.109	-.086
25.4	.959	-.173	-.079
34.4	.982	-.206	-.034
43.4	.980	-.220	.001
52.4	.956	-.222	.042
61.3	.960	-.219	.081
70.4	.968	-.205	.116
79.5	.981	-.185	.142
88.4	.989	-.159	.162
98.1	.997	-.133	.171
106.4	.995	-.108	.179
115.5	.996	-.076	.185
133.5	.998	-.030	.190
151.5	.997	.016	.189
160.5	.967	.050	.184
169.5	.999	.079	.172
178.4	.865	.087	.097
187.5	1.003	.059	.190
196.5	1.000	.107	.168
205.6	1.009	.123	.160
214.5	1.004	.140	.140
223.5	1.015	.152	.123
232.6	1.009	.160	.100
241.4	1.006	.166	.083
251.0	1.011	.166	.057
259.5	1.003	.165	.037
270.2	1.006	.160	.010
277.5	.981	.154	-.009
286.6	.946	.139	-.027
295.6	.902	.122	-.052
304.6	.843	.097	-.065
313.7	.734	.053	-.075
322.8	.719	-.002	-.060
331.8	.712	-.012	-.032
340.9	.682	-.019	-.001
350.1	.649	-.035	.014
356.0	.692	-.036	.018
358.4	.710	-.036	.019

RADIUS = .868

ANGLE	VX/V	VT/V	VR/V
-1.6	.588	.033	-.004
0.0	.582	.026	-.016
5.7	.562	.003	-.058
16.4	.821	-.125	-.161
23.7	.904	-.146	-.139
34.4	.946	-.165	-.085
41.5	.932	-.167	-.047
52.4	.894	-.157	.008
59.5	.912	-.146	.054
70.4	.943	-.141	.095
77.6	.969	-.128	.120
88.3	.988	-.097	.142
95.7	.987	-.078	.143
106.3	.988	-.049	.151
113.7	.989	-.032	.153
124.4	.988	-.006	.154
131.9	.991	.010	.157
142.5	.985	.035	.162
149.9	.993	.059	.160
155.3	.993	.071	.162
161.2	.994	.087	.162
169.5	.960	.146	.163
178.7	.684	.026	.008
179.7	.629	.058	-.001
185.8	.999	.112	.168
190.0	.996	.124	.160
196.7	.992	.143	.146
203.8	.991	.166	.134
214.6	.996	.184	.107
221.7	1.005	.195	.090
232.6	1.001	.205	.069
239.7	1.005	.212	.048
250.5	.998	.216	.022
257.8	.996	.215	.003
268.5	.969	.214	-.026
275.8	.952	.200	-.042
293.7	.858	.173	-.081
304.5	.783	.154	-.104
311.7	.712	.135	-.115
322.5	.639	.054	-.096
329.6	.626	.054	-.057
340.5	.627	.068	-.032
347.6	.589	.046	-.019
355.0	.588	.034	-.005
358.4	.588	.033	-.004
360.0	.582	.026	-.016

TABLE 10 - LISTING OF THE MEAN VELOCITY COMPONENT RATIOS, THE MEAN ADVANCE ANGLES AND OTHER DERIVED QUANTITIES AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE ARS-50 WITHOUT NOZZLE OR PROPELLER

ARS WAKE SURVEY WITHOUT PROPELLER OR NOZZLE
PROPELLER DIAMETER = 10.50 FEET JV = .932

RADIUS =	.451	.591	.735	.868	.299	.300	.400	.500	.600	.700	.800	.900	1.000
VXBAR =	1.009	.970	.928	.891	1.049	1.049	1.023	.996	.968	.938	.910	.891	.891
VTBAR =	-.003	.061	-.001	.048	-.210	-.209	-.056	.033	.054	.003	.010	.048	.048
VRBAR =	.156	.063	.071	.037	.369	.367	.214	.112	.065	.074	.060	.037	.037
1-WVX =	1.025	1.006	.982	.958	0.000	1.049	1.036	1.021	1.005	.988	.970	.954	.940
1-WX =	1.171	1.051	1.002	.971	0.000	1.393	1.190	1.095	1.041	1.008	.986	.964	.946
BBAR =	33.63	25.29	20.54	16.68	52.76	52.58	38.37	30.09	24.99	21.65	18.58	16.13	14.61
BPOS =	5.76	4.24	2.97	2.57	10.82	10.76	6.74	5.18	4.12	3.21	2.56	2.47	2.18
THETA =	55.00	60.00	40.00	87.50	32.50	32.50	50.00	60.00	60.00	42.50	37.50	87.50	87.50
BNEG =	-6.67	-4.63	-5.67	-5.83	-14.46	-14.37	-8.34	-5.62	-4.63	-5.34	-5.85	-5.65	-5.16
THETA =	320.00	317.50	350.00	5.00	322.50	322.50	320.00	320.00	317.50	347.50	350.00	5.00	5.00

VXBAR IS CIRCUMFERENTIAL MEAN LONGITUDINAL VELOCITY.
VTBAR IS CIRCUMFERENTIAL MEAN TANGENTIAL VELOCITY.
VRBAR IS CIRCUMFERENTIAL MEAN RADIAL VELOCITY.
1-WVX IS VOLUMETRIC MEAN WAKE VELOCITY WITHOUT TANGENTIAL CORRECTION.
1-WX IS VOLUMETRIC MEAN WAKE VELOCITY WITH TANGENTIAL CORRECTION.
BBAR IS MEAN ANGLE OF ADVANCE.
BPOS IS VARIATION BETWEEN THE MAXIMUM AND MEAN ADVANCE ANGLES (DELTA BETA PLUS).
BNEG IS VARIATION BETWEEN THE MINIMUM AND MEAN ADVANCE ANGLES (DELTA BETA MINUS).
THETA IS ANGLE IN DEGREES AT WHICH CORRESPONDING BPOS OR BNEG OCCURS.

TABLE 11 - HARMONIC ANALYSIS OF THE LONGITUDINAL VELOCITY COMPONENT RATIOS AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE ARS-50 WITHOUT NOZZLE OR PROPELLER

ARS WAKE SURVEY WITHOUT PROPELLER OR NOZZLE
PROPELLER DIAMETER = 10.50 FEET UV = .932

HARMONIC ANALYSES OF LONGITUDINAL VELOCITY COMPONENT RATIOS (VX/V)

HARMONIC =	1	2	3	4	5	6	7	8
RADIUS = .451								
AMPLITUDE =	.0543	.0659	.0413	.0196	.0159	.0132	.0099	.0172
PHASE ANGLE =	293.2	314.6	350.1	1.5	67.2	190.7	212.1	229.0
RADIUS = .591								
AMPLITUDE =	.0759	.0747	.0362	.0128	.0075	.0124	.0042	.0113
PHASE ANGLE =	300.3	321.7	353.1	351.3	78.3	225.8	223.2	248.6
RADIUS = .735								
AMPLITUDE =	.1121	.0905	.0442	.0290	.0040	.0197	.0094	.0115
PHASE ANGLE =	286.5	309.1	344.9	330.0	308.0	266.7	219.9	263.9
RADIUS = .868								
AMPLITUDE =	.1394	.1114	.0414	.0361	.0056	.0357	.0146	.0268
PHASE ANGLE =	286.2	303.8	356.1	314.9	357.6	272.7	192.6	261.5
RADIUS = .299								
AMPLITUDE =	.0651	.0761	.0621	.0491	.0259	.0143	.0281	.0308
PHASE ANGLE =	249.4	283.1	340.3	350.9	47.8	179.8	209.4	219.0
RADIUS = .300								
AMPLITUDE =	.0648	.0759	.0619	.0488	.0258	.0143	.0279	.0307
PHASE ANGLE =	249.7	283.3	340.3	351.0	47.9	179.8	209.4	219.0
RADIUS = .400								
AMPLITUDE =	.0512	.0654	.0464	.0268	.0189	.0139	.0146	.0210
PHASE ANGLE =	280.7	305.9	346.9	357.9	60.9	184.5	210.5	224.5
RADIUS = .500								
AMPLITUDE =	.0605	.0683	.0381	.0150	.0130	.0126	.0067	.0144
PHASE ANGLE =	299.6	319.8	352.4	2.9	72.5	199.9	214.9	234.8
RADIUS = .600								
AMPLITUDE =	.0782	.0754	.0370	.0140	.0065	.0124	.0046	.0108
PHASE ANGLE =	298.6	320.7	351.7	348.7	76.5	229.3	225.4	249.6
RADIUS = .700								
AMPLITUDE =	.1037	.0858	.0434	.0259	.0028	.0166	.0063	.0099
PHASE ANGLE =	288.0	311.4	344.8	333.6	316.3	261.2	224.9	262.0
RADIUS = .800								
AMPLITUDE =	.1264	.1001	.0439	.0333	.0050	.0268	.0116	.0172
PHASE ANGLE =	285.5	305.9	348.0	323.1	319.0	271.6	207.4	263.6
RADIUS = .900								
AMPLITUDE =	.1394	.1114	.0414	.0361	.0056	.0357	.0146	.0268
PHASE ANGLE =	286.2	303.8	356.1	314.9	357.6	272.7	192.6	261.5
RADIUS = 1.000								
AMPLITUDE =	.1394	.1114	.0414	.0361	.0056	.0357	.0146	.0268
PHASE ANGLE =	286.2	303.8	356.1	314.9	357.6	272.7	192.6	261.5

TABLE 12 - HARMONIC ANALYSIS OF THE TANGENTIAL VELOCITY COMPONENT RATIOS AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE ARS-50 WITHOUT NOZZLE OR PROPELLER

ARS WAKE SURVEY WITHOUT PROPELLER OR NOZZLE
PROPELLER DIAMETER = 10.50 FEET JV = .932

HARMONIC ANALYSES OF TANGENTIAL VELOCITY COMPONENT RATIOS (VT/V)

HARMONIC =	1	2	3	4	5	6	7	8
RADIUS = .451								
AMPLITUDE =	.2141	.0199	.0069	.0082	.0036	.0117	.0007	.0091
PHASE ANGLE =	214.8	175.9	313.6	65.5	333.6	80.4	87.6	100.6
RADIUS = .591								
AMPLITUDE =	.1965	.0107	.0117	.0143	.0118	.0098	.0051	.0072
PHASE ANGLE =	215.5	200.4	24.7	52.3	46.5	108.0	70.8	151.5
RADIUS = .735								
AMPLITUDE =	.1787	.0233	.0175	.0140	.0133	.0083	.0065	.0024
PHASE ANGLE =	208.7	169.9	70.1	71.1	57.8	101.8	48.6	152.4
RADIUS = .868								
AMPLITUDE =	.1750	.0281	.0165	.0110	.0135	.0098	.0113	.0050
PHASE ANGLE =	206.8	190.6	109.7	123.3	94.5	137.3	92.4	179.6
RADIUS = .299								
AMPLITUDE =	.2345	.0594	.0195	.0131	.0227	.0209	.0083	.0228
PHASE ANGLE =	207.6	158.9	226.6	176.0	248.0	46.3	264.6	54.6
RADIUS = .300								
AMPLITUDE =	.2343	.0591	.0194	.0129	.0225	.0208	.0082	.0226
PHASE ANGLE =	207.7	159.0	226.9	175.7	248.1	46.5	264.6	54.8
RADIUS = .400								
AMPLITUDE =	.2205	.0236	.0083	.0056	.0072	.0137	.0018	.0120
PHASE ANGLE =	213.0	167.4	270.1	99.2	270.6	67.1	258.6	79.5
RADIUS = .500								
AMPLITUDE =	.2080	.0141	.0062	.0110	.0063	.0107	.0027	.0079
PHASE ANGLE =	215.7	187.4	348.2	55.0	26.3	92.6	79.0	122.8
RADIUS = .600								
AMPLITUDE =	.1949	.0114	.0122	.0146	.0120	.0097	.0051	.0067
PHASE ANGLE =	215.0	193.7	29.6	53.2	46.5	106.4	65.7	150.9
RADIUS = .700								
AMPLITUDE =	.1816	.0209	.0168	.0147	.0133	.0085	.0061	.0029
PHASE ANGLE =	209.9	169.3	62.2	64.9	52.8	99.0	43.6	147.4
RADIUS = .800								
AMPLITUDE =	.1756	.0261	.0175	.0119	.0130	.0082	.0078	.0028
PHASE ANGLE =	207.1	176.6	86.1	89.3	72.2	115.7	68.7	170.5
RADIUS = .900								
AMPLITUDE =	.1750	.0281	.0165	.0110	.0135	.0098	.0113	.0050
PHASE ANGLE =	206.8	190.6	109.7	123.3	94.5	137.3	92.4	179.6
RADIUS = 1.000								
AMPLITUDE =	.1750	.0281	.0165	.0110	.0135	.0098	.0113	.0050
PHASE ANGLE =	206.8	190.6	109.7	123.3	94.5	137.3	92.4	179.6

DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.

2. DEPARTMENTAL REPORTS, A SEMIFORMAL SERIES, CONTAIN INFORMATION OF A PRELIMINARY, TEMPORARY, OR PROPRIETARY NATURE OR OF LIMITED INTEREST OR SIGNIFICANCE. THEY CARRY A DEPARTMENTAL ALPHANUMERICAL IDENTIFICATION.

3. TECHNICAL MEMORANDA, AN INFORMAL SERIES, CONTAIN TECHNICAL DOCUMENTATION OF LIMITED USE AND INTEREST. THEY ARE PRIMARILY WORKING PAPERS INTENDED FOR INTERNAL USE. THEY CARRY AN IDENTIFYING NUMBER WHICH INDICATES THEIR TYPE AND THE NUMERICAL CODE OF THE ORIGINATING DEPARTMENT. ANY DISTRIBUTION OUTSIDE DTNSRDC MUST BE APPROVED BY THE HEAD OF THE ORIGINATING DEPARTMENT ON A CASE-BY-CASE BASIS.

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